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September, 1980

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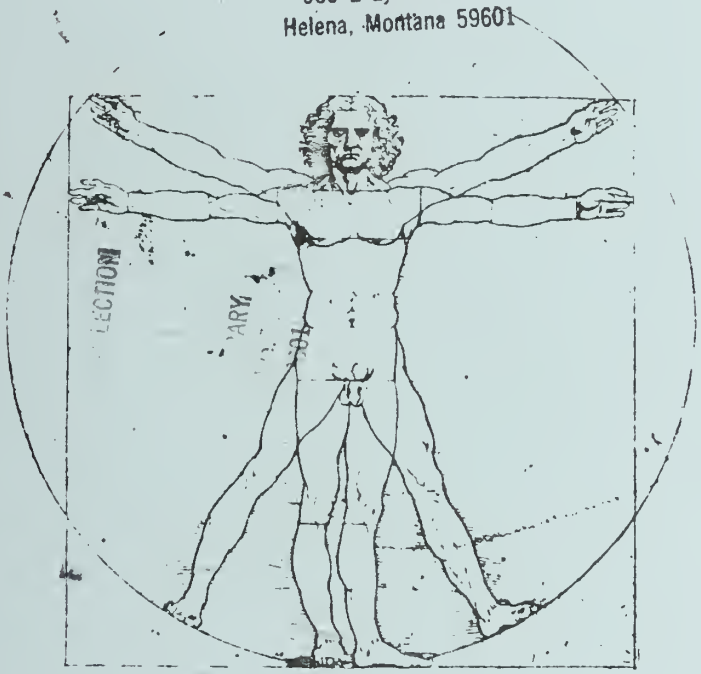

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MISSOULA VALLEY
DISPERSION STUDY

by

Harold Robbins
Michael Machler
Terri Middlemist
Larry Zimmerman

MONTANA AIR POLLUTION STUDY

AIR QUALITY BUREAU

Environmental Sciences Division
Department of Health and Environmental Sciences
Helena, Montana 59601

September, 1980

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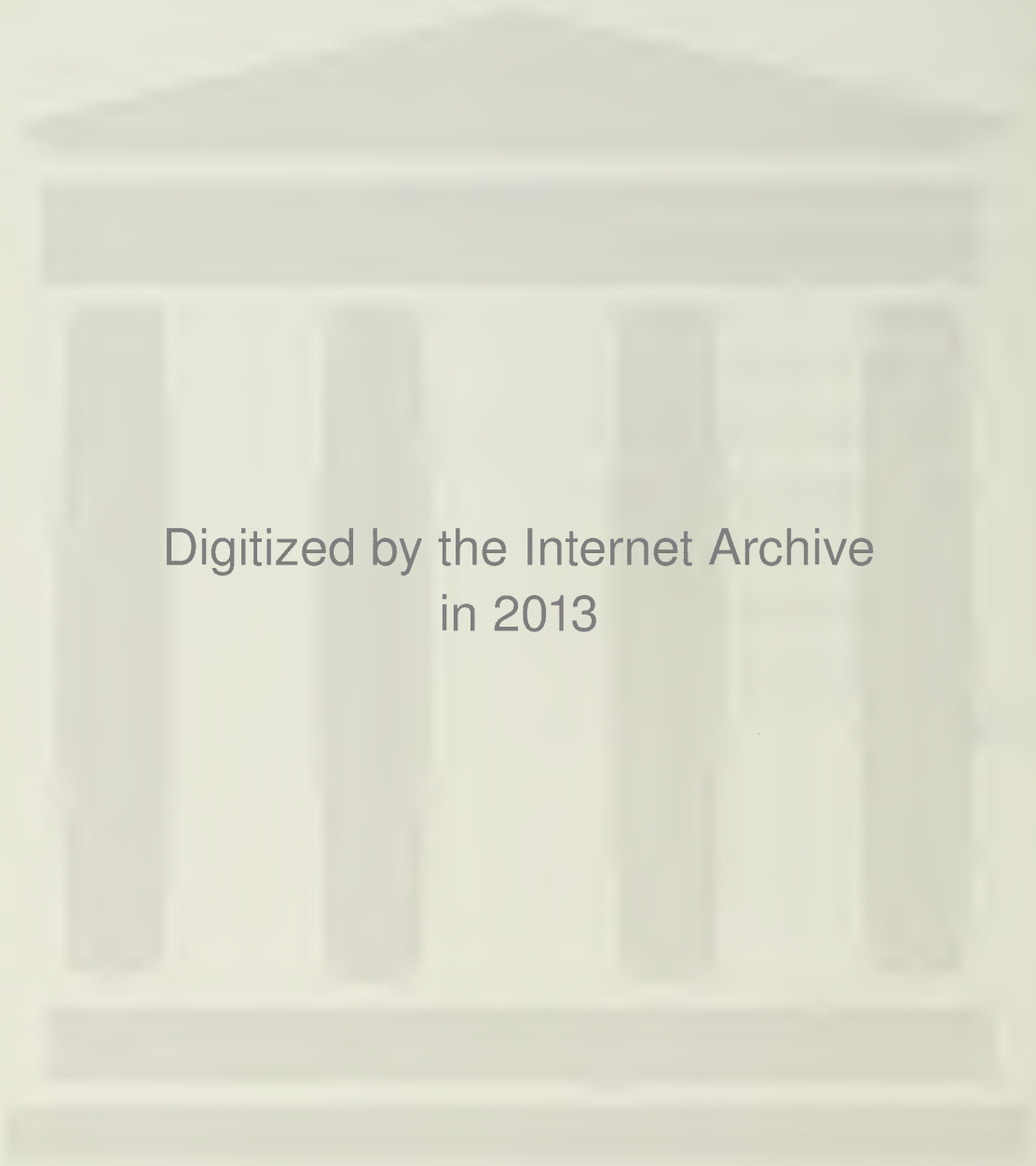

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FOREWORD

This is one of a series of technical reports presenting results from the Montana Air Pollution Study (MAPS), a special air monitoring and health effects project of the Air Quality Bureau, Montana Department of Health and Environmental Sciences. The 1977 Montana Legislature provided the MAPS project with $1.07 million for the 1977-1979 biennium to improve understanding of how air pollution affects health in Montana.

The various MAPS activities have been grouped into five major categories for purposes of project management: Health Effects; Air Quality; Meteorology/Modeling; Emission Inventory; and Statistics and Data Systems. Results from each of these technical areas are to be presented in a series of reports prepared by the personnel directly involved in each category of MAPS. A final report to the public also will be prepared.

PREFACE

This report discusses results of the dispersion study conducted in the Missoula Valley of western Montana. Partially funded by Champion Packaging (formerly Hoerner-Waldorf), division of Champion International Corporation, the study was designed and coordinated by James W. Gelhaus, staff meteorologist with the Air Quality Bureau, with Michael Machler, independent meteorologist in charge of data and analysis. Aaron L. Zimmerman, Certified Consulting Meteorologist in charge of MAPS meteorological field operations; Terri Middlemist, independent meteorologist; and Alben Myren, ambient air monitoring station operator in Missoula, conducted the field study.

EXECUTIVE SUMMARY

The Air Quality Bureau, Montana Department of Health and Environmental Sciences, conducted a meteorological study of the Missoula Valley in western Montana during 1978-1979. The study, which was funded by the 1977 Montana Legislature and Champion Packaging (formerly Hoerner-Waldorf), a division of Champion International Corporation, included the use of surface and upper air meteorological instrumentation. Data were obtained on mixing heights, atmospheric stability, inversion height, intensity and duration, and other related meteorological parameters, and reduced to computer format and summarized into monthly tables. This report presents the results of the Missoula Valley Dispersion Study.

I. INTRODUCTION

Meteorological conditions strongly influence the frequency and severity of air pollution concentrations in the air. The ability of the lower atmosphere to disperse, dilute and mix pollutants released into it can vary immensely with daily, weekly, or seasonal meteorological fluctuations. These meteorological variations have a major influence on air pollution concentrations. Therefore, it is essential that such meteorological variations be measured and compared with the associated changes in pollution to determine the relationship between air pollution and meteorology. Only through the analysis of air quality and meteorology together is it possible to describe, anticipate, or predict accurately ambient pollution concentrations.

The lower atmospheric air movement patterns typical of the mountainous terrain in the western part of the country are far more erratic than those found over flat terrain. Valley-mountain terrain causes air movement patterns that frequently vary greatly over short distances. The city of Missoula is located in a valley surrounded by mountains. In this area the escape of pollutants from the valley "bowl" is very limited under certain meteorological conditions, such as low winds and temperature inversions.

The Missoula Valley consists of a portion of the Bitterroot Valley to the south, and the Clark Fork Valley extending from Missoula to twenty miles to the west-northwest. The valley is shielded by the Continental Divide sixty to eighty miles to the east and the Bitterroot Range twenty miles to the southwest; this mountainous enclosure results in a semiarid climate. The area experiences frequent climatic temperature inversions during the fall and winter.

The meteorological network established in Montana in the past, primarily by the National Weather Service, has provided a basis for describing or forecasting the general weather conditions that apply to large areas, usually the size of several counties. The major forecast emphasis has been on temperature, precipitation, and the occurrence of storms accompanied by high wind, blizzards, flooding, and other such phenomena. This network is not adequate to provide data needed to identify and to understand local meteorological effects on air pollution.

Therefore, one of the objectives of the Montana Air Pollution Study (MAPS) was to define more specifically the primary meteorological parameters that affect air pollution levels in the various study areas. The Missoula Valley was studied from May 1978 through November 1979.

A diurnal wind pattern, called "mountain" or "valley" winds, is evident in the Missoula Valley. During the day when surface heating causes air currents to rise, confluent winds favor upward vertical motion. (Valley wind means upward out of the valley or up the mountain slopes.) The down-valley component or mountain wind occurs at night, bringing cooler air into the valley. These mountain winds often serve to hold atmospheric air pollution in the valley area, as the cool, dense air stays close to the surface.

During the spring and summer, nighttime inversions, which are caused by the radiational cooling of the earth's surface, are common. Because the earth's surface suffers a net loss of heat, it is cooler at the surface than aloft. The degree of heat loss affects the depth and duration of the inversion, which usually begins to dissipate with the incoming radiation after sunrise.

In order to measure the airflow pattern within the valley, MAPS established a meteorological and ambient air sampling network. See Tables 1, 2 and 3. Along with the sites established by MAPS, surface meteorological data were obtained from Champion Packaging and the National Weather Service.

The Champion Packaging site, located 5.4 miles northwest of U.S.F.S. Northern Forest Fire Laboratory, had an average monthly wind speed of 2.4 meters per second (m/sec), an average wind direction of southwest, and a prevailing average wind direction of northwest.

The National Weather Service showed an average monthly wind speed of 2.6 m/sec with a westerly prevailing direction. The average daily temperature ranges from 18^{o}C in the spring and summer to -3^{0}C in the autumn and winter.

The Lions' Park site has an average monthly wind speed of 1.6 m/sec, an average wind direction of south-southwest, and a prevailing direction of west-southwest.

The Olofson site had an average monthly wind speed of 1.5 m/sec and a westerly monthly prevailing direction.

The Stiegler site had an average monthly wind speed of 1.5 m/sec with a west-northwest prevailing monthly direction.

The University of Montana site had an average monthly wind speed of 2.8 m/sec with a prevailing monthly direction of west.

More information on surface meteorology is provided in the "Discussion and Results" section of this report.

TABLE 1

AMBIENT AIR QUALITY SAMPLING NETWORK SITE LOCATIONS
MISSOULA, MONTANA

SITE	ADDRESS	PARAMETERS	DISTANCE AND DIRECTION FROM U.S.F.S. NORTHERN FOREST FIRE LABORATORY	ELEVATION
Courthouse	Broadway and Woody Ave.	Particulate	6.1 mi. 127°	3200 ft. MSL
Hoerner Waldorf #1	West of Missoula (Frenchtown)	H_2S, SO_2 Particulate	5.2 mi. 292°	3140 ft. MSL
Hoerner Waldorf #2	West of Missoula (Frenchtown)	H_2S, SO_2 Particulate	5.4 mi. 282°	3060 ft. MSL
Hoerner Waldorf #3	West of Missoula (Frenchtown)	H_2S, SO_2 Particulate	4.4 mi. 206°	3260 ft. MSL
Johnson Bell Field	Highway 10 West	Particulate	0.8 mi. 129°	3190 ft. MSL
Lions' Park	Bancroft and Kent Ave.	Particulate, CO, NO, NO_2, NO_x, O_3, SO_2, Total Hydrocarbons, Visibility	6.7 mi. 141°	3180 ft. MSL
McLeod Park	Washington and Kent Ave. West	Particulate	6.3 mi. 145°	3180 ft. MSL
Memorial Rose Park	Franklin Street	Particulate	6.5 mi. 138°	3190 ft. MSL
Schilling	Schilling and Cannon Ave.	Particulate	5.9 mi. 150°	3170 ft. MSL

All distances, directions, and elevations approximate values.

TABLE 2

METEOROLOGICAL NETWORK SITE LOCATIONS
MISSOULA, MONTANA

SITE	ADDRESS	PARAMETERS	DISTANCE AND DIRECTION FROM U.S.F.S. NORTHERN FOREST FIRE LABORATORY		ELEVATION
Hoerner Waldorf #1	West of Missoula (Frenchtown)	Wind Speed Wind Direction	5.2 mi.	292°	3140 ft. MSL
KECI TV	TV Mountain (Point 6)	Temperature			6970 ft. MSL
Lions' Park	Bancroft and Kent Avenue	Wind Speed Wind Direction Temperature Dewpoint Temperature Solar Radiation Upper Air Measurements	6.7 mi.	141°	3180 ft. MSL
MAPS Office	525 West Pine Ave.	Volz Sunphotometer	5.8 mi.	128°	3190 ft. MSL
National Weather Service	Johnson Bell Field - Highway 10 West	Wind Speed Wind Direction Temperature Dewpoint Temperature Humidity Solar Radiation Cloud Cover Pressure	0.8 mi.	129°	3190 ft. MSL
C. Olofson	4425 Bitterroot Road (Bitterroot Drainage)	Wind Speed Wind Direction	6.9 mi.	172°	3125 ft. MSL
J. Stiegler	Mullan Road (Grass Valley Farms) (Clark Fork Drainage)	Wind Speed Wind Direction	2.1 mi.	228°	3090 ft. MSL
University of Montana	University of Montana Physical Plant Complex (Hellgate Drainage)	Wind Speed Wind Direction	7.2 mi.	128°	3210 ft. MSL
U.S.F.S. Northern Forest Fire Laboratory	Highway 10 West	Upper Air Measurements Acoustic Radar	0		3210 ft. MSL

All distances, directions and elevations approximate value.

TABLE 3

POINT SOURCE EMISSIONS
MISSOULA, MONTANA

SITE / ADDRESS	DISTANCE AND DIRECTION FROM U.S.F.S. NORTHERN FOREST FIRE LABORATORY		ELEVATION
Champion Building Products Division of Champion International Corporation (formerly Intermountain) Bitterroot and Milwaukee Tracks (Off Orange Street by McCormick Park)	5.6 mi.	134°	3160 ft. MSL
Champion Packaging Division of Champion International Corporation (formerly Hoerner-Waldorf) West of Missoula (Frenchtown)	5.4 mi.	297°	3060 ft. MSL
Evans Products Company Cemetary Road	4.2 mi.	123°	3180 ft. MSL
Louisiana Pacific Corporation Cemetary Road	3.7 mi.	123°	3180 ft. MSL
White Pine and Sash 1301 Scott	5.1 mi.	125°	3190 ft. MSL

All distances, directions, and elevations approximate values.

II. INSTRUMENTATION AND DATA COLLECTION

Situated in the southeastern section of urban Missoula, the Lions' Park air monitoring site is in the northeastern corner of the park, which has an area of approximately one square city block. Lions' Park is bordered to the north and west by commercial areas and to the south and east by residential areas. (See Figure 1.) The site is equipped to monitor the following meteorological parameters: wind direction; temperature; dewpoint temperature; solar radiation; and visual range. The system used to collect the data is a Climatronics Corporation Model Main Frame F460.* The sensors are mounted atop a ten-meter tower located on the north side of the trailer. The system provides a convenient package in that all data are recorded on one chart located inside the trailer.

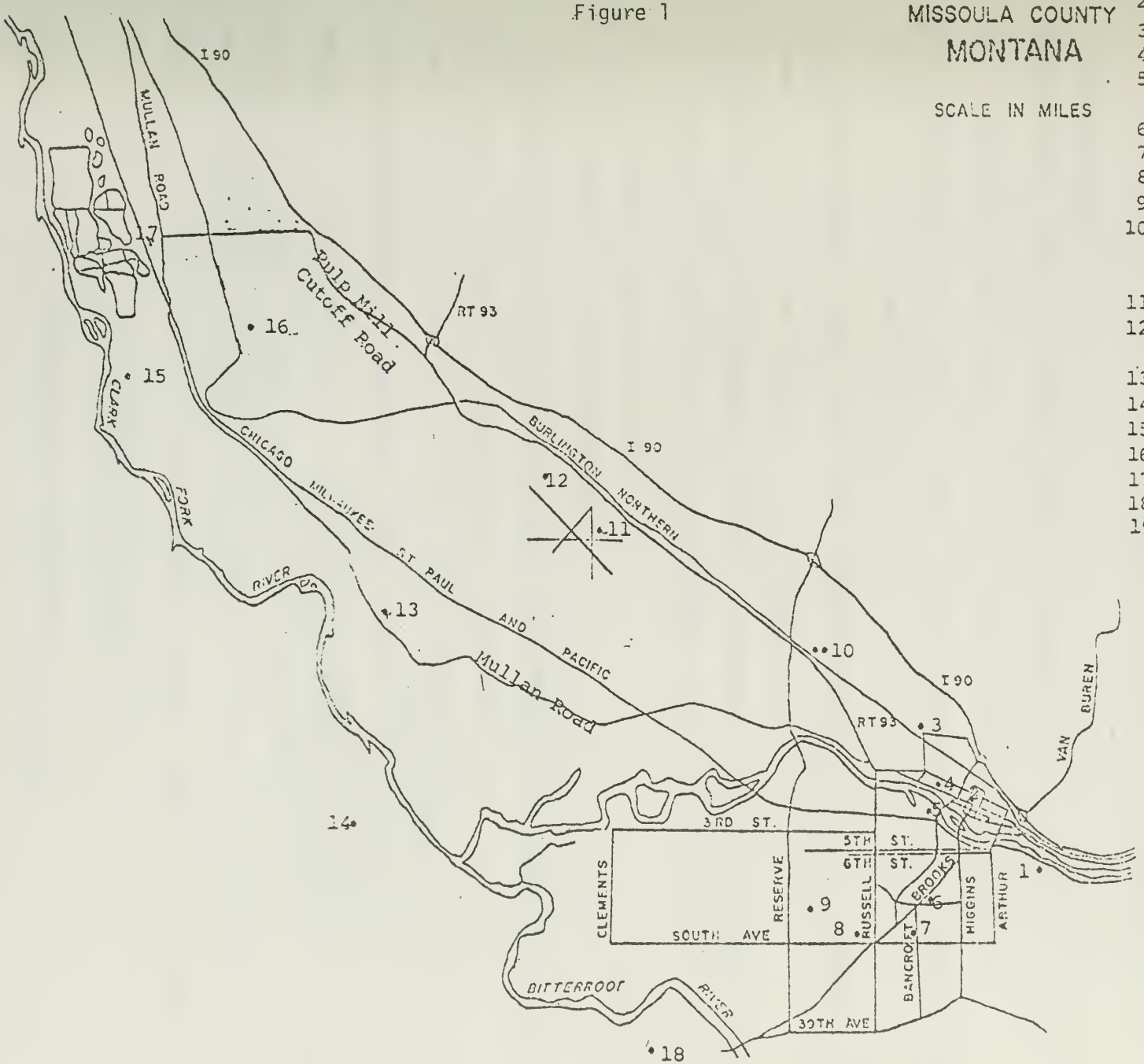
Data were recorded from charts from December 1977 through September 1979 by Air Quality Bureau personnel in Helena. In September 1979 the system was connected with a Western Telecomputing ICIS 850 data acquisition system.

Measurements of upper level wind speed and direction were taken through the use of a single theodolite/pilot balloon tracking system. The balloons were precalibrated for a constant ascent rate and released Mondays, Wednesdays and Fridays, twice a day (one-half hour after sunrise and 1400 MST), weather permitting. The data were analyzed by the Air Quality Bureau's computer in Helena.

The Lions' Park site also was equipped to measure the following air quality parameters: sulfur dioxide; nitrogen dioxide; total suspended particulates; fine particulates; trace elements; carbon monoxide; and total

*Mention of an equipment supplier does not constitue an endorsement.

Figure 1


MISSOULA
MISSOULA COUNTY
MONTANA
SCALE IN MILES
1. University of Mont.
2. Courthouse
3. White Pine & Sash
4. MAPS Office
5. Champion Building Products
6. Memorial Rose Park
7. Lions' Park
8. McLeod Park
9. Schilling
10. Evans Products Co. Louisiana Pacific Corp.
11. National Weather Svc.
12. U.S.F.S. Northern Forest Fire Lab.
13. Stiegler
14. Champion Pkg. #3
15. Champion Pkg. #2
16. Champion Pkg. #1
17. Champion Packaging
18. Olofson
19. KECI TV
I 90
MULLAN ROAD
Pulp Mill Cutoff Road
RT 93
CLARK FORK RIVER
CHICAGO MILWAUKEE ST PAUL AND PACIFIC
BURLINGTON NORTHERN
I 90
Mullan Road
RT 93
VAN BUREN
3RD ST.
5TH ST.
6TH ST.
CLEMENTS
RESERVE
RUSSELL
BROOKS
HIGGINS
ARTHUR
SOUTH AVE
BANCROFT
30TH AVE
BITTERROOT RIVER
N

hydrocarbons. (See MAPS Air Monitoring Instrumentation, October, 1979). (See Figure 2)

Surface meteorological data also are obtained from the National Climatic Center in Asheville, North Carolina. The data are obtained on computer cards for the Missoula National Weather Service (NWS) station, located at Johnson Bell Field, approximately six miles west of downtown Missoula. Data include surface wind speed, wind direction, temperature, dewpoint temperature, pressure, solar radiation, precipitation and cloud cover.

The Missoula NWS station also provided a breakdown of hourly visibility into quadrants during daylight hours from April 1978 through May 1979.

Surface wind speed and wind direction are measured continuously at the Clifford Olofson site located on Bitterroot Road (Highway 93), approximately two miles southwest of the Missoula city limits, near the mouth of the Bitterroot Valley. A house is south of the site, and a barn is to the west-northwest. The buildings are not of considerable height and do not obstruct air flow patterns. (See Figure 3)

Surface wind speed and wind direction are measured continuously at the John Stiegler site located in the Grass Valley Farms area, approximately seven miles west-northwest of Missoula. (See Figure 4)

The University of Montana site is located on university property in the most northeastern corner of the Physical Plant Complex on the eastern end of the campus. The site is bordered by the Clark Fork River to the north, and experiences extreme wind conditions from the mouth of the Hellgate Canyon to the east. A low-lying maintenance garage is located to the southeast. The site is equipped to monitor surface wind speed and wind direction continuously. (See Figure 5)

Figure 2

Lions' Park Ambient Air Monitoring Site

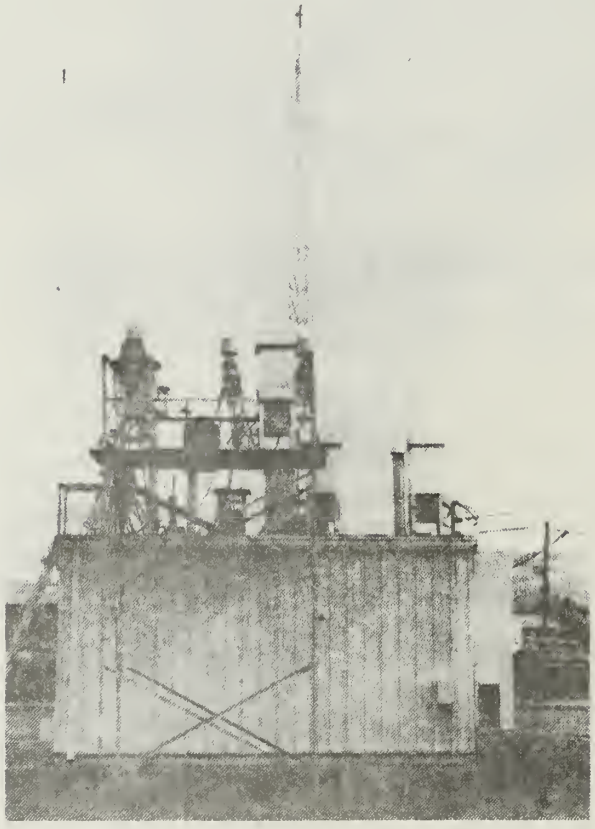


Figure 3

Olofson Meteorological Site

Figure 4

Stiegler Meteorological Site

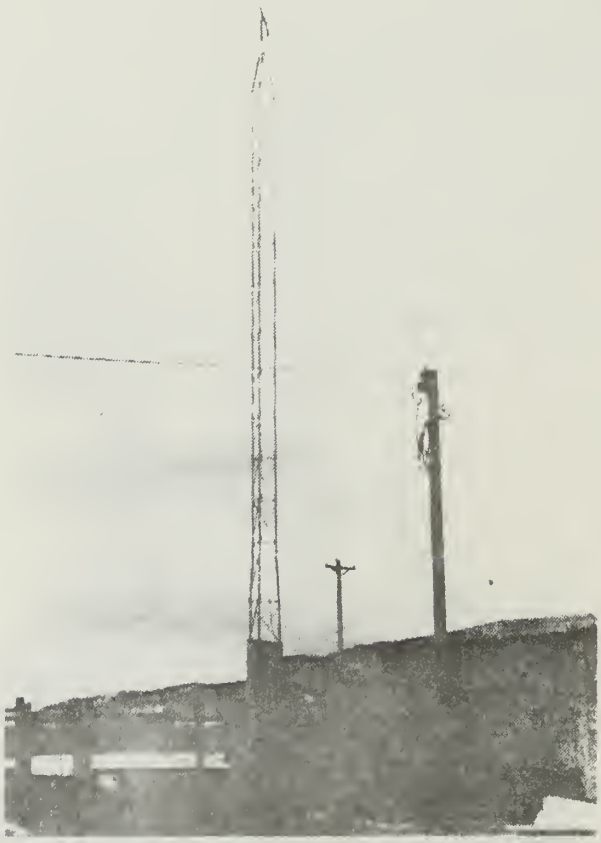
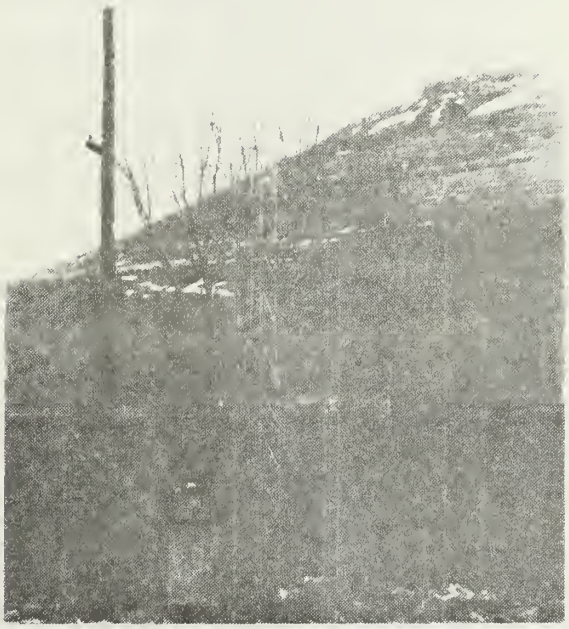


Figure 5

University of Montana Meteorological Site



The equipment used at the Olofson, Stiegler, and University of Montana sites is a Climatronics Corporation Mark III Wind Measuring System, which consists of a wind vane and anemometer atop a ten-meter tower. The anemometer and wind vane relay data to the recorder unit located in a shelter at the base of the tower.

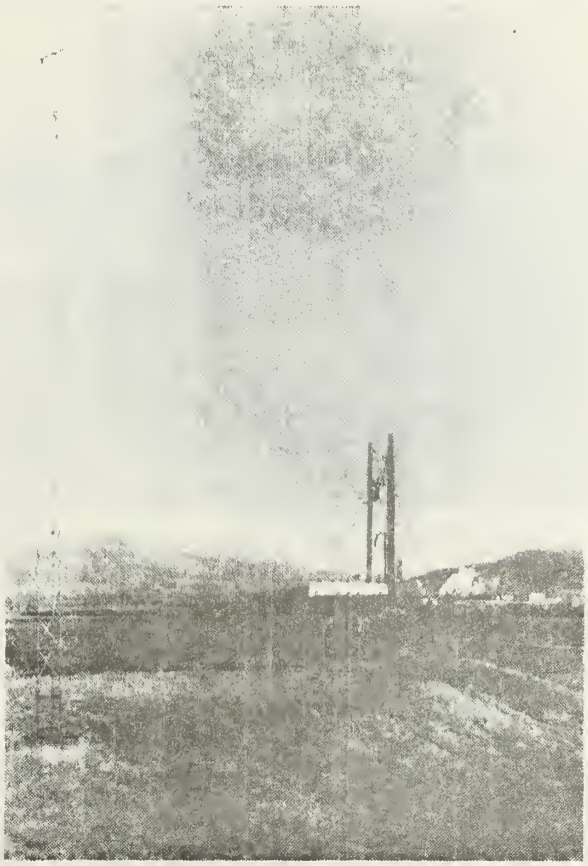
Wind speed is measured by a three-cup anemometer, coupled to a light chopper, which converts the rotation speed of the cups to a frequency proportional to the wind speed. The data are read from charts by either MAPS personnel in Missoula or Air Quality Bureau personnel in Helena, and reduced for computer analysis. Output from the computer includes tables of monthly wind speed, monthly wind direction, and a monthly wind rose. The computer also is programmed to produce a wind rose diagram.

The Champion Packaging Company also provides surface wind speed and wind direction data to the Air Quality Bureau in Helena. The data are obtained from the Number One site, located three-quarters of a mile southwest of the main complex. The system used to obtain the data is a Climatronics Corporation Mark III Wind Measuring System, and the data are reduced to computer format by MAPS personnel. (See figure 6)

KECI Television provides temperature data from the transmitter station located on TV Mountain, which is approximately 3700 feet above the valley floor and ten miles north of Missoula. The air temperatures are tabulated hourly, using a remote sensor installed in a standard Cotton Region Shelter (a white louvered box with a flat double roof mounted four feet above the ground on a four-legged stand). The data are used for lapse rate calculations.

Figure 6

Champion Packaging
Meteorological Site



Turbidity measurements, which are measured by a Volz sun photometer, are taken Monday through Friday, when the sun is unobscured by clouds, at 0900, 1200 and 1500 MST. The measurements are taken by the MAPS staff at the St. Patrick School of Nursing, located approximately one-half mile west of downtown Missoula. Observations for June, July, and August 1979 were taken at the Missoula County Health Department office located three blocks northeast of St. Patrick's School of Nursing.

Upper level wind and temperature measurements are made at the Northern Forest Fire Laboratory, approximately seven miles northwest of the city. A trailer, which is on loan from the U.S. Forest Service, is situated in an open field one-half mile west of the main buildings. (See Figure 7) The measurements are made through the use of a single theodolite and pilot balloon tracking system. The pilot balloons, which are precalibrated for constant rates, are released Mondays, Wednesdays, and Fridays, twice a day (one-half hour after sunrise and 1400 MST), weather permitting. (See Table 4). Observations are taken at thirty-second intervals and recorded on a standard form that provides for a recording of azimuths, elevations, and other pertinent data.

Weather-Measure thirty-gram balloons and a Warren-Knight Model 84 Balloon Theodolite are used. A theodolite is an optical instrument consisting of a sighting telescope mounted so that it is free to rotate around horizontal and vertical azes, with graduated scales to measure the angles of rotation.[1]

1. Glossary of Meteorology, Edited by Ralph E Huschke, American Meteorological Society, 45 Beacon St., Boston, Mass., 1970

Figure 7

Northern Forest Fire
Laboratory Meteorological Site

TABLE 4

Lift Rates for Various Balloons*

Weight No.	Weight (g)	Lift Rate (m/sec)+
1	72.0	2.75
2	33.9	1.78
3	15.0	1.28
4	5.7	0.78

*Rates apply to Weather Measure 30g balloons only

+Reference Super (1972)

Temperature minisondes are attached to the pilot balloons to obtain a continuous trace of atmospheric temperature. The minisondes, 403 MHZ FM powered by nine-volt batteries, are manufactured by Aero-Aqua, Inc. The receiver, also manufactured by Aero-Aqua, Inc., has linear temperature output, while the recording system is an Esterline Angus Miniservo Strip-Chart recorder.

Analysis of the pilot balloon/temperature sonde data is performed by computer programs through the DHES/AQB computer in Helena. Output from these programs includes wind speed and wind direction at selected levels, inversion base height and thickness, inversion type (Holzworth Classification), lapse rate, mixing height, and average wind speed through the mixed layer.

In the normal atmosphere, the temperature decreases with height; a temperature inversion is a layer of air in which the temperature increases with height. The layer of air is termed stable because the temperature and moisture distribution does not allow for the vertical exchanges of air. Due to the stagnant conditions in an inversion, the level of particulates may increase significantly.

The data from the pilot balloons and temperature sondes show the atmospheric temperature structure and the wind speed and direction below, through, and above the inversion layer.

The Holzworth Classification of Inversions describes the inversion layer by the temperature lapse rate (distribution of temperature in regard to distance) within the layer. (See Table 5.)

The mixing layer is defined as the layer, from the surface upward, through which pollutants can be mixed by convection. The height of the mixing layer is determined graphically by the intersection of the adiabatic lapse rate with the natural atmospheric temperature. The adiabatic lapse

TABLE 5-1

Holzworth Lapse Rate Categories (Modified)

Values in deg C/100m

Non-Inversion Class	Lapse Rate	Description
1	< -1.60	Very Superadiabatic
2	-1.21 to -1.60	Superadiabatic
3	-0.81 to -1.20	Near Dry Adiabatic
4	-0.41 to -0.80	Near Standard Atmosphere
5	0.00 to -0.40	Weak Lapse

Inversion Class	Lapse Rate	Description
1	0.00 to +0.47	Weak Inversion
2	+0.48 to +1.14	Moderate Inversion
3	+1.15 to +2.82	Strong Inversion
4	+2.83 to +6.00	Very Strong Inversion
5	> +6.00	Extreme Inversion

(Holzworth, 1974)

rate is the rate at which a parcel of dry air will cool as it rises: $9.8^{o}C/Km$. MAPS calculated a morning and afternoon mixing height.

An acoustic radar system is used to monitor and record atmospheric stability continuously. The system, manufactured by Aero-vironment Inc., emits a brief 1600 Hz (1600 cycles per second) pulse and then listens for the echoes to bounce back from turbulence aloft. The stylus is moved across the recorder paper so that height on the chart represents height in the atmosphere, and the stylus darkens the chart when an echo is received[2]. The system consists of the radar transmitter/receiver dish in a soundproof enclosure and a transceiver-display unit.

The ability of the acoustic radar to monitor the atmosphere continuously allows for determination of trends in stability of the layer(s) of air from the surface to 1000 meters; breakup and formation times of stable layers (inversions); and base, height, and thickness of the stable layers.

With input from NWS climatic data (wind speed, cloud cover, precipitation), a stability classification can be computed. The following is a schematic of the logic flow used in the computer program to determine the A through F classification for each two-hour period, where A represents the most unstable and F the most stable atmospheric condition. Neutral and stable atmospheric conditions do not allow for the vertical exchanges of air, thus resulting in particulate accumulation.

---

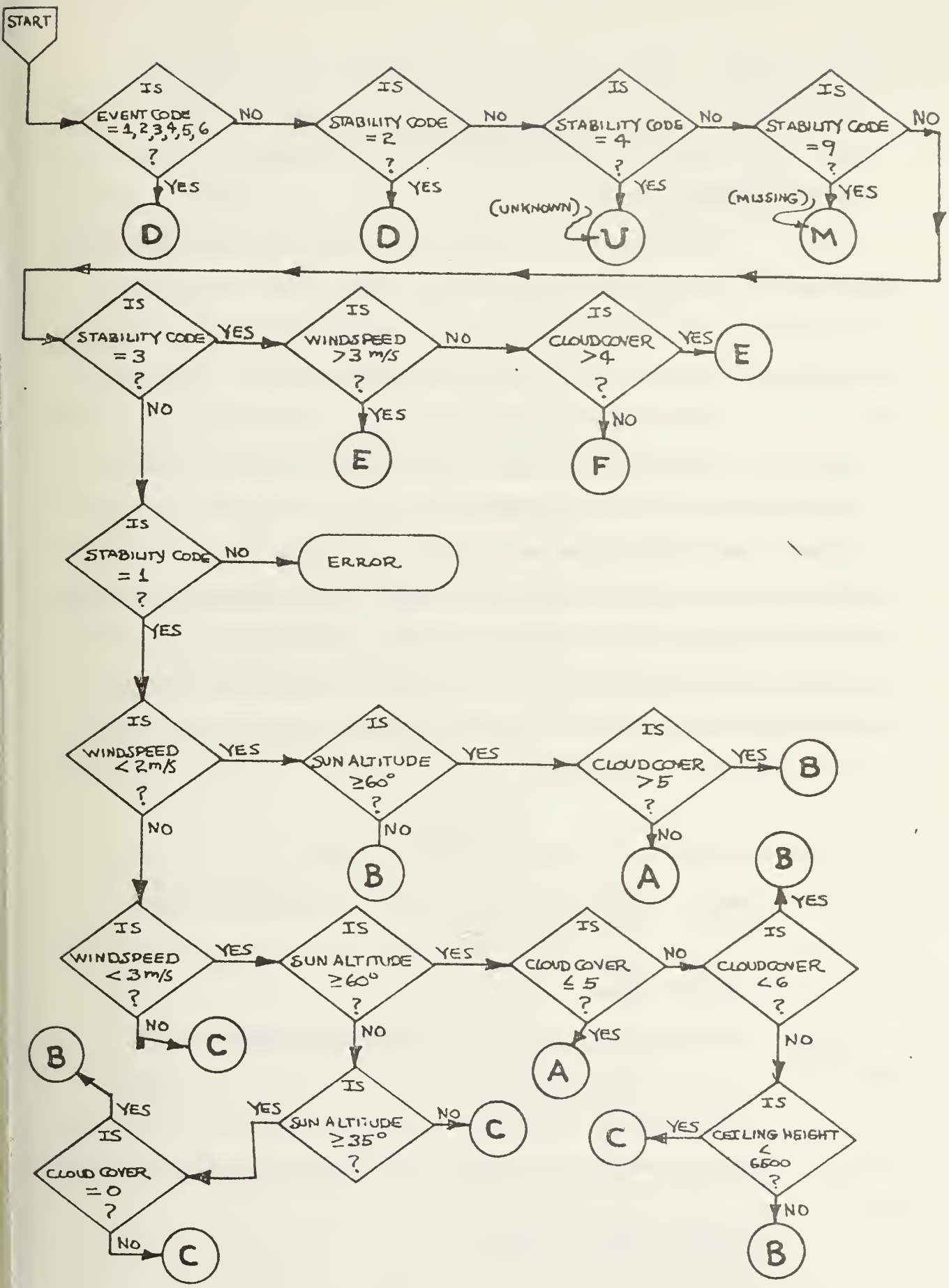
2. AeroVironment, Inc. informational booklet.

KEY TO LOGIC FLOW CHART

S-Stability of lower 100 meters
- 1-unstable
- 2-neutral
- 3-stable
- 4-unknown
- 9-missing

E-Event
- 1-precipitation-light intensity (.01 to .06 in./hour)
- 2-precipitation-moderate intensity (.06 to .20 in./hour)
- 3-precipitation-heavy intensity (.20 in./hour)
- 4-precipitation-intensity unknown
- 5-frontal passage
- 6-inversion breakup
- 7-inversion formation

Cloud Cover-total sky cover rated in tenths (0-9)


START
IS EVENT CODE = 1,2,3,4,5,6 ?
NO
YES
D
IS STABILITY CODE = 2 ?
NO
YES
D
IS STABILITY CODE = 4 ?
NO
YES
(UNKNOWN)
U
IS STABILITY CODE = 9 ?
NO
YES
(MISSING)
M
IS STABILITY CODE = 3 ?
YES
NO
IS WINDSPEED > 3 m/s ?
NO
YES
E
IS CLOUDCOVER > 4 ?
YES
E
NO
F
IS STABILITY CODE = 1 ?
NO
ERROR
YES
IS WINDSPEED < 2m/s ?
YES
NO
IS SUN ALTITUDE ≥60° ?
YES
NO
B
IS CLOUDCOVER > 5 ?
YES
B
NO
A
IS WINDSPEED < 3m/s ?
YES
NO
C
IS SUN ALTITUDE ≥60° ?
YES
NO
IS CLOUD COVER ≤ 5 ?
NO
YES
A
IS CLOUDCOVER < 6 ?
YES
B
NO
IS SUN ALTITUDE ≥35° ?
YES
NO
C
IS CLOUD COVER = 0 ?
YES
NO
C
B
IS CEILING HEIGHT < 6500 ?
YES
C
NO
B

III. DISCUSSION AND RESULTS

A. Surface Meteorology

The air circulation pattern in the Missoula Valley as it relates to air quality and pollution characteristics is complicated by the terrain, which creates low-level wind patterns that vary significantly not only from one portion of the valley to another, but also from day to night. During the night and early morning hours, the Missoula Valley represents an area of confluent winds. During the day, when surface heating causes air currents to rise, confluent winds favor upward vertical motion, although it is most likely that at night, they often serve to hold atmospheric air pollution in the valley areas, as the cool, dense air remains close to the ground surface. In order to measure the flow pattern of the valley, MAPS established a meteorological sampling network. MAPS also obtained surface meteorological data from Champion Packaging and the National Weather Service (NWS). Table 2 lists each site and the parameters collected. Figure 1 is a map of all the sites.

Tables 6 through 11 list the monthly and seasonal data for each site. Average wind speed, in meters per second (m/sec), is an hourly average at all sites except the NWS. For all NWS observations, the data are an average of a minute period during the hour.

An hourly average wind direction was recorded at Champion Packaging, Lions' Park, and the NWS. An hourly prevailing wind direction was recorded from the Olofson, Stiegler, and University of Montana (UM) sites. A prevailing wind direction is the wind direction sector most frequently observed during the hour.

Wind direction was recorded in degrees (0^{o} - 360^{o}). Average hourly wind direction at Champion Packaging and NWS was recorded to the nearest ten degrees, resulting in 36 sectors. Data from the Olofson, Lions' Park, Stiegler, and UM sites indicated a prevailing direction with 16 sectors (360^{o} N; $22\frac{1}{2}^{o}$ NNW; 45^{o} NW; etc.).

Tables 6 through 11 also list the average monthly wind range and peak gust. The wind range is a measure of the variability in wind direction; example: 10^{o} - constant wind direction; 360^{o} - very erratic wind direction. Peak gust is the highest wind speed recorded during the hour.

The lowest average monthly wind speeds occur during the autumn and winter (see tables 6-11). With the exception of the UM site, the highest average monthly wind speed occurs during the spring. The lowest average hourly wind speed generally occurs in the early morning hours when vertical mixing is at a minimum; the highest average hourly wind speed occurs in the afternoon hours when vertical mixing is at a maximum due to surface heating. The table below lists the highest and lowest average hourly wind speed for each site.

TABLE 5-2

Champion Packaging:	0.9 m/sec	Autumn	morning
	5.8 m/sec	Spring	1700 MST
Lions' Park	0.5 m/sec	Winter	0200 MST
	4.5 m/sec	Spring	1600 MST
National Weather Service	0.8 m/sec	Autumn, Winter	morning
	5.6 m/sec	Spring	1700 MST
Olofson	0.8 m/sec	Autumn	morning
	4.9 m/sec	Spring	1400 MST
Stiegler	0.2 m/sec	Autumn	0700 MST
	4.2 m/sec	Spring	1600 MST
UM	1.3 m/sec	Summer	0900 MST
	5.4 m/sec	Winter	0200 MST

TABLE 6

Climatological Data
Champion Packaging
Missoula, Montana

Month/Year	Average Wind Speed m/sec	Average Wind Direction Degrees	Prevailing Average Wind Direction Degrees
1977 Dec.	2.2	229 SW	360 N
1978 Jan.	1.8	191 S	360 N
Feb.	2.2	193 SSW	157 SSE
Mar.	2.7	208 SSW	360 N
Apr.	3.1	231 SW	360 N
May	3.1	223 SW	360 N
Jun.	2.7	218 SW	360 N
Jul.	2.7	243 WSW	337 NNW
Aug.	2.7	245 WSW	315 NW
Sep.	2.2	247 WSW	315 NW
Oct.	1.8	230 SW	360 N
Nov.	2.7	209 SSW	135 SE
Dec.	2.2	232 SW	315 NW
1979 Jan.	1.3	217 SW	337 NNW
Feb.	2.2	209 SSW	337 NNW
Mar.	2.2	223 SW	360 N
Apr.	2.7	246 WSW	270 W
May	3.1	234 SW	270 W
Jun.	2.7	244 WSW	270 W
Jul.	2.7	241 WSW	315 NW
Aug.	2.7	222 SW	270 W
Sep.	2.2	237 WSW	315 NW
Oct.	1.8	222 SW	337 NNW
Nov.	1.3	229 SW	337 NNW
Dec.			
1980 Jan.			
Feb.			
77-78 Winter	2.0	204 SSW	360 N
1978 Spring	3.0	220 SW	360 N
1978 Summer	2.7	236 SW	315 NW
1978 Autumn	2.2	229 SW	315 NW
78-79 Winter	1.9	212 SSW	337 NNW
1979 Spring	2.7	234 SW	270 W
1979 Summer	2.7	236 SW	270 W
1979 Autumn	1.7	229 SW	337 NNW

TABLE 7

Climatological Data
National Weather Service
Missoula, Montana

Month/Year	Average Wind Speed m/sec	Average Wind Direction Degrees	Average Daily Temp. °C	Average Maximum Daily Temp. °C	Average Minimum Daily Temp. °C	Average Pressure mb	Precip. in
1977 Dec.	2.2	270 W	- 4.2	- 0.6	- 7.7	902.1	2.88
1978 Jan.	2.4	270 W	- 4.3	- 1.2	- 7.6	905.2	1.15
Feb.	2.6	112 ESE	- 2.6	1.3	- 6.5	903.8	0.66
Mar.	2.9	270 W	4.3	10.6	- 1.9	903.5	0.67
Apr.	3.4	270 W	7.8	14.2	1.3	901.1	1.08
May	3.0	292 WNW	9.0	14.8	3.8	904.8	1.98
Jun.	2.8	315 NW	15.3	23.9	6.7	905.2	0.77
Jul.	2.9	270 W	18.5	27.4	9.6	905.5	0.57
Aug.	2.8	292 WNW	17.5	25.9	9.0	905.5	1.11
Sep.	2.6	270 W	12.8	19.9	5.7	904.8	1.78
Oct.	2.0	315 NW	7.4	16.2	- 1.4	909.6	0.01
Nov.	2.6	90 E	- 2.9	1.7	- 7.6	908.2	1.00
Dec.	2.7	292 WNW	- 8.9	- 5.0	-12.9	906.2	0.99
1979 Jan.	0.9	--- ----	-14.6	-10.0	-16.2	908.1	1.25
Feb.	2.5	90 E	- 3.6	0.3	- 7.5	901.4	1.04
Mar.	2.9	270 W	2.2	7.7	- 3.3	904.4	1.22
Apr.	3.7	292 WNW	6.6	12.9	0.3	902.4	1.04
May	3.4	270 W	11.2	18.8	3.6	903.4	0.74
Jun.	3.4	292 WNW	16.8	25.5	8.0	904.7	0.67
Jul.	3.4		20.7	30.2	11.1	905.1	0.77
Aug.	2.1		15.0	29.2	11.9	903.7	1.31
Sep.	2.6		16.3	26.0	6.5	905.8	0.05
Oct.	2.1		8.9	15.8	2.1	905.4	0.97
Nov.	1.5		- 2.7	2.1	- 7.4	909.8	0.50
Dec.	2.4		- 0.4	2.8	- 3.7	906.4	0.81
1980 Jan.	2.9		- 8.7	- 2.8	-13.1	905.1	1.80
Feb.	2.1		- 1.3	2.1	- 4.8	905.1	0.60
Mar.	3.1		1.4	6.3	- 3.5	901.7	0.88
77-78 Winter	2.4	270 W	- 3.7	- 0.2	- 7.3	903.7	1.60
1978 Spring	3.1	292 WNW	7.1	13.2	7.1	903.1	1.20
1978 Summer	2.8	292 WNW	17.1	25.8	8.4	905.4	0.80
1978 Autumn	2.4	270 W	5.8	11.4	- 1.1	907.6	0.90
78-79 Winter	2.4	90 E	- 7.2	- 5.1	-13.4	905.4	1.10
1979 Spring	3.3	270 W	6.7	13.1	0.2	903.4	1.00
1979 Summer	3.3		19.4	28.4	10.4	904.5	0.90
1979 Autumn	2.0		7.6	14.6	0.4	907.0	0.50
79-80 Winter	2.5		- 3.5	0.1	- 7.2	905.5	1.10

TABLE 8

Climatological Data
Lions' Park
Missoula, Montana

Month/Year	Average Wind Speed m/sec	Average Wind Direction Degrees		Prevailing Average Wind Direction Degress		Average Wind Range Degrees	Average Peak Gust m/sec	Average Daily Temperature °C
1977 Dec.	1.4	187	S	202	SSW			
1978 Jan.	1.1	189	S	202	SSW			
Feb.	1.0	171	S	202	SSW			
Mar.	1.6	187	S	247	WSW			
Apr.	2.1	201	SSW	247	WSW			
May	2.0	212	SSW	247	WSW			
Jun.	2.0	244	WSW	360	N			
Jul.								
Aug.								
Sep.	1.8	208	SSW	225	SW	212	3.6	
Oct.	1.3	211	SSW	202	SSW	223	2.7	
Nov.	1.3	204	SSW	270	W	219	3.1	
Dec.	1.8	223	SW	270	W	223	3.6	
1979 Jan.	0.9	211	SSW	225	SW	180	1.8	
Feb.								
Mar.								
Apr.	2.7	211	SSW	270	W	179	4.5	
May	2.7	203	SSW	270	W	181	4.9	13.1
Jun.	2.5	201	SSW	315	NW		4.7	17.2
Jul.	2.3	194	SSW	315	NW		4.2	20.4
Aug.	1.6	183	S	315	NW		3.2	19.5
Sep.	1.2	190	S	112	ESE		2.5	15.1
Oct.	1.1	169	S	112	ESE		2.3	10.1
Nov.	0.7	184	S	135	SE			
Dec.	1.7	210	SSW	270	W			
1980 Jan.								
Feb.								
77-78 Winter	1.2	183	S	202	SSW			
1978 Spring	1.9	200	SSW	247	WSW			
1978 Summer								
1978 Autumn	1.5	208	SSW	225	SW			
78-79 Winter*	1.3	216	SW	225	SW			
1979 Spring**	2.7	283	WNW	270	W	180	4.7	13.1
1979 Summer	2.1	192	SSW	315	NW		4.0	19.1
1979 Autumn	1.0	180	S	112	ESE		2.4#	13.3#
79-80 Winter								

* Dec.,78, Jan., 79 only
** Apr., 79, May, 79 only
\# Sep., 79, Oct., 79 only

TABLE 9

Climatological Data
Olofson Site
Missoula, Montana

Month/Year	Average Wind Speed m/sec	Average Wind Direction Degress		Prevailing Wind Direction Degrees		Average Wind Range Degrees	Average Peak Gust m/sec
1978 May							
Jun.						187	4.1
Jul.	1.5	233	SW	315	NW		
Aug.	1.3	234	SW	247	WSW		
Sep.	1.3	212	SSW	337	NNW		
Oct.	1.2	213	SSW	247	WSW		
Nov.	1.6	192	SSW	225	SW	149	3.0
Dec.							
1979 Jan.							
Feb.							
Mar.	No Data - Recorder Malfunction						
Apr.	2.2	199	SSW	360	N	174	4.0
May	No Data - Recorder Malfunction						
Jun.	2.0	230	SW	247	WSW	206	3.8
Jul.	1.8	198	SSW	---	---	201	3.4
Aug.	1.9	191	S	270	W	197	3.7
Sep.	No Data - Recorder Malfunction						
Oct.	No Data - Recorder Malfunction						
Nov.	1.1	210	SSW	180	S	178	2.2
Dec.	1.6	201	SSW	202	SSW	170	3.4
1980 Jan.							
Feb.							
1978 Summer*	1.4	234	SW	337	NNW		
1978 Autumn	1.3	208	SSW	247	WSW		
78-79 Winter							
1979 Spring**	2.2	199	SSW	360	N	174	4.0
1979 Summer	1.9	209	SSW	247	WSW	202	3.6
1979 Autumn#	1.1	210	SSW	180	S	178	2.2
79-80 Winter						178	

* Jul., 78, Aug., 78 only
** Apr., 79 only
\# Nov,, 79 only

TABLE 10

Climatological Data
Stiegler Site
Missoula, Montana

Month/Year	Average Wind Speed m/sec	Average Wind Direction Degrees		Prevailing Wind Direction Degrees		Average Wind Range Degrees	Average Peak Gust m/sec
1978 May	2.3	245	WSW	315	NW	189	4.2
Jun.	1.7	222	SW	315	NW	228	3.6
Jul.	1.9	121	SE	112	ESE	193	3.8
Aug.	No Data - Recorder Malfunction						
Sep.	No Data - Recorder Malfunction						
Oct.	No Data - Recorder Malfunction						
Nov.	No Data - Recorder Malfunction						
Dec.	2.2	232	SW	315	NW	159	4.0
1979 Jan.	0.4	188	S	360	N	153	1.8
Feb.	1.3	202	SSW	270	W	215	2.2
Mar.							
Apr.	1.9	222	SW	270	W	167	3.5
May	1.9	214	SW	247	WSW	184	5.0
Jun.	1.6	240	WSW	292	WNW	199	3.4
Jul.	1.7	139	SE	135	SE	195	3.4
Aug.	1.7	104	ESE	157	SSE	164	3.3
Sep.	No Data - Recorder Malfunction						
Oct.	No Data - Recorder Malfunction						
Nov.	0.5	136	SE	292	WNW	171	1.2
Dec.	1.1	156	SSE	135	SE	173	2.6
1980 Jan.	1.4	147	SSE	67	ENE		
Feb.							
1978 Spring*	2.3	245	WSW	315	NW	189	4.2
1978 Summer**	1.7	182	S	45	NE	219	3.6
1978 Autumn	No Data - Recorder Malfunction						
78-79 Winter	1.0	199	SSW	315	NW	171	2.5
1979 Spring#	1.8	217	SW	247	WSW	177	5.3
1979 Summer	1.6	171	S	112	ESE	171	3.4
1979 Autumn##	0.5	136	SE	292	WNW	171	1.2
79-80 Winter							

* May 78 only
** Jun. 78, July 78, only
\# Apr., 79, May, 79 only
Nov., 79 only

TABLE 11

Climatological Data
University of Montana Site
Missoula, Montana

Month/Year	Average Wind Speed m/sec	Average Wind Direction Degrees		Prevailing Wind Direction Degrees		Average Wind Range Degrees	Average Peak Gust m/sec
1978 May	2.6	215	SW	270	W		4.8
Jun.	2.5						4.7
Jul.	2.4	190	S	270	W		4.3
Aug.	2.5	190	S	270	W		4.3
Sep.	2.7	189	S	270	W	178	4.5
Oct.	2.7	192	SSW	270	W	155	4.5
Nov.	No Data - Recorder Malfunction						
Dec.	3.6	208	SSW	270	W	143	5.8
1979 Jan.	2.7	218	SW	135	SE	144	4.0
Feb.	3.6	184	S	112	FSE	159	5.8
Mar.				112	ESE		
Apr.	3.1	202	SSW	270	W	156	5.0
May	3.0	197	SSW	270	W	164	5.1
Jun.	2.6	205	SSW	270	W	182	4.7
Jul.	2.6	192	SSW	270	W	195	4.7
Aug.	2.7	174	S	247	WSW	162	4.8
Sep.	2.4	185	S	112	ESE	162	4.2
Oct.	2.4	178	S	112	ESE	157	4.2
Nov.	1.9	193	SSW	112	ESE	147	3.4
Dec.	3.1	167	SSE	112	ESE		
1980 Jan.	3.6	168	SSE	112	ESE		
Feb.							
1978 Spring*	2.6	215	SW	270	W		4.8
1978 Summer	2.5	190	S **	270	W**		4.4
1978 Autumn#	2.7	194	SSW	270	W	166	4.5
78-79 Winter	3.2	205	SSW	270	W	148	5.2
1979 Spring##	3.0	198	SSW	270	W	163	5.0
1979 Summer	2.6	191	S	270	W	180	4.7
1979 Autumn	2.4	188	S	112	ESE	155	3.9
79-80 Winter							

* May, 78 only
** Jul., 78, Aug., 78 only
\# Sep., 78, Oct., 78 only
Apr., 79, May., 79 only

Tables 12 through 17 show wind speed and direction for Missoula from site by season for selected hours and diurnal wind patterns. For each site, the prevailing wind direction is dependent on its location in the Missoula Valley. All sites except the UM site were placed in relatively open areas. The UM site, which was placed directly in the mouth of the Hellgate Canyon, experienced very little cross wind flow.

The general average wind direction flow for the Missoula Valley is south-southwest for all seasons. Along with the diurnal change in wind speed, a diurnal change in wind direction is evident. However, the direction shift is dependent on each site's location.

Tables of wind rose frequency and wind rose plots were prepared on a monthly basis for each site. These tables and rose diagrams, in Appendix A, show the distribution of prevailing wind direction and average speed for each direction.

TABLE 12

Diurnal Wind Pattern
Champion Packaging
Missoula, Montana

	Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		
	Mid	1.3	192	SSW	360	N	Mid	2.4	220	SW	360	N	
	04	1.3	210	SSW	360	N	04	2.1	231	SW	360	N	
	08	2.1	213	SSW	360	N	08	1.3	239	WSW	337	NNW	
77-78	12	2.1	197	SSW	360	N	12	3.4	221	SW	292	WNW	1978
Winter	16	2.1	208	SSW	337	NNW	16	4.5	211	SSW	---	---	Spring
	20	1.9	185	S	360	N	20	2.7	224	SW	225	SW	
	Mid	1.9	247	WSW	337	NNW	Mid	2.1	228	SW	315	NW	
	04	1.5	190	S	360	N	04	1.9	241	WSW	360	N	
1978	08	1.3	256	WSW	337	NNW	08	1.8	244	WSW	360	N	1978
Summer	12	2.4	249	WSW	247	WSW	12	2.4	224	SW	---	---	Autumn
	16	4.3	259	W	315	NW	16	2.8	190	S	---	---	
	20	3.9	243	WSW	270	W	20	2.4	221	SW	270	W	
	Mid	1.8	225	SW	337	NNW	Mid	1.9	224	SW	180	S	
	04	1.9	242	WSW	337	NNW	04	1.8	239	WSW	337	NNW	
78-79	08	1.9	218	SW	337	NNW	08	1.8	259	W	315	NW	1979
Winter	12	1.8	219	SW	270	W	12	3.3	243	SW	270	W	Spring
	16	2.4	201	SSW	90	E	16	4.3	232	SW	270	W	
	20	1.8	226	SW	315	NW	20	3.1	219	SW	315	NW	
	Mid	2.1	234	SW	270	W	Mid	1.6	223	SW	360	N	
	04	1.6	226	SW	360	N	04	1.3	234	SW	360	N	
1979	08	1.6	264	W	315	NW	08	1.2	250	WSW	337	NNW	1979
Summer	12	2.5	245	WSW	315	NW	12	1.8	235	SW	180	S	Autumn
	16	4.3	251	WSW	292	WNW	16	2.7	235	SW	180	S	
	20	4.0	229	SW	270	W	20	1.9	230	SW	202	SSW	

TABLE 13

Diurnal Wind Pattern
National Weather Service
Missoula, Montana

	Time	Ave. Wind Speed m/sec	Prev. Average Wind Direction Degrees		Time	Ave. Wind Speed m/sec	Prev. Average Wind Direction Degrees		
	05	1.1	112	ESE	05	1.0	112	ESE	
	08	1.0	292	WNW	08	1.1	292	WNW	
77-78	11	1.1	90	E	11	1.5	292	WNW	1978
Winter	17	1.1	315	NW	17	2.0	292	WNW	Spring
	20	1.1	---	---	20	1.2	292	WNW	
	23	1.0	292	WNW	23	1.1	---	---	
	05	0.6	---	---	05	0.8	292	WNW	
	08	0.8	157	SSE	08	0.7	112	ESE	
1978	11	1.2	292	WNW	11	1.0	112	ESE	1978
Summer	17	2.2	292	WNW	17	1.4	270	W	Autumn
	20	1.7	292	WNW	20	1.1	292	WNW	
	23	1.1	270	W	23	1.0	90	E	
	05	0.9	90	E	05	1.0	270	W	
	08	0.9	90	E	08	1.0	---	---	
78-79	11	0.9	270	W	11	1.5	292	WNW	1979
Winter	17	1.0	270	W	17	2.2	270	W	Spring
	20	0.8	90	E	20	1.7	270	W	
	23	1.0	---	---	23	1.1	292	WNW	

TABLE 14

Diurnal Wind Pattern
Lions' Park
Missoula, Montana

	Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		
	Mid	1.0	161	SSE	112	ESE	Mid	1.3	172	S	112	ESE	
	04	1.1	172	S	202	SSW	04	1.1	175	S	247	WSW	
77-78	08	1.1	185	S	202	SSW	08	1.4	212	SSW	247	WSW	1978
Winter	12	1.3	189	S	202	SSW	12	2.6	229	SW	270	W	Spring
	16	1.31	208	SSW	202	SSW	16	3.1	247	WSW	337	NNW	
	20	1.0	164	SSE	112	ESE	20	1.7	178	S	112	ESE	
	Mid						Mid	1.3	177	S	135	SE	
	04						04	1.2	199	SSW	270	W	
	08						08	1.2	236	SW	202	SSW	
1978	12						12	1.6	240	WSW	225	SW	1978
Summer	16						16	1.9	227	SW	337	NNW	Autumn
	20						20	1.3	184	S	135	SE	
	Mid	1.1	200	SSW	225	SW	Mid	1.6	176	S	90	E	
	04	1.1	201	SSW	225	SW	04	1.3	166	SSE	180	S	
78-79	08	1.3	225	SW	270	W	08	2.0	216	SW	225	SW	1979
Winter*	12	1.6	222	SW	225	SW	12	3.4	235	SW	270	W	Spring**
	16	1.6	232	SW	225	SW	16	4.5	244	WSW	292	WSW	
	20	1.3	185	S	225	SW	20	2.4	178	S	270	W	
	Mid	1.4	132	SE	112	ESE	Mid	0.8	145	SE	135	SE	
	04	1.3	163	SSE	112	ESE	04	0.7	171	S	247	WSW	
1979	08	1.6	214	SW	225	SW	08	0.7	184	S	180	S	1979
Summer	12	2.4	199	SSW	---	---	12	1.2	210	SSW	225	SW	Autumn
	16	3.6	256	WSW	292	WNW	16	1.6	209	SSW	180	S	
	20	2.4	171	S	225	SW	20	1.2	148	SSE	112	ESE	

* Dec., 78; Jan., 79 only
** Apr., 79; May, 79 only

TABLE 15

Diurnal Wind Pattern
Olofson Site
Missoula, Montana

	Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		
	Mid	1.0	223	SW	225	SW	Mid	1.4	207	SSW	225	SW	
	04	0.8	234	SW	225	SW	04	1.1	220	SW	247	WSW	
1978	08	1.0	216	SW	315	NW	08	1.3	178	S	225	SW	1978
Summer*	12	1.9	251	WSW	315	NW	12	1.6	177	S	202	SSW	Autumn
	16	2.4	248	WSW	247	WSW	16	1.5	217	SW	247	WSW	
	20	1.2	212	SSW	315	NW	20	1.3	221	SW	225	SW	
	Mid						Mid	1.3	221	SW	247	WSW	
	04						04	1.8	198	SSW	225	SW	
78-79	08						08	1.8	150	SSE	90	E	1979
Winter	12						12	3.1	177	S	202	SSW	Spring*
	16						16	3.6	167	SSE	360	N	
	20						20	2.2	219	SW	270	W	
	Mid	1.4	225	SW	225	SW	Mid	0.9	189	S	180	S	
	04	1.2	225	SW	270	W	04	0.8	220	SW	180	S	
1979	08	1.6	177	S	23	NNE	08	0.8	227	SW	---	---	1979
Summer	12	2.4	160	SSE	23	NNE	12	1.2	249	WSW	315	NW	Autumn#
	16	3.0	223	SW	337	NNW	16	1.4	240	WSW	247	WSW	
	20	2.1	232	SW	247	WSW	20	1.3	199	SSW	180	S	

* July, 78; Aug. 78 only
** April, 79 only
# Nov., 79 only

TABLE 16

Diurnal Wind Pattern
Stiegler Site
Missoula, Montana

	Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		
	Mid	1.4	244	WSW	337	NNW	Mid	1.0	157	SSE	45	NE	
	04	1.3	238	WSW	315	NW	04	0.7	154	SSE	45	NE	
1978	08	2.1	254	WSW	315	NW	08	1.2	160	SSE	---	---	1978
Spring*	12	3.6	260	W	270	W	12	2.6	185	S	270	W	Summer**
	16	3.4	273	W	337	NNW	16	3.2	214	SW	270	W	
	20	2.1	256	WSW	292	WNW	20	1.7	136	SE	23	NNE	
	Mid						Mid	0.7	206	SSW	---	---	
	04						04	0.7	202	SSW	360	N	
1978	08	No Data					08	0.9	168	SSE	90	E	78-79
Autumn	12	Recorder Malfunction					12	0.9	171	S	112	ESE	Winter
	16						16	1.3	187	S	---	---	
	20						20	1.1	227	SW	360	N	
	Mid	1.1	193	SSW	---	---	Mid	1.0	151	SSE	112	ESE	
	04	0.9	200	SSW	180	S	04	0.8	110	ESE	67	ENE	
1979	08	1.2	210	SSW	247	WSW	08	1.3	175	S	112	ESE	1979
Spring#	12	2.8	228	SW	270	W	12	2.0	163	SSE	23	NNE	Summer
	16	3.7	248	WSW	337	NNW	16	3.3	172	S	45	NE	
	20	2.1	245	WSW	247	WSW	20	1.8	177	S	135	SE	
	Mid	0.5	98	E	157	SSE							
	04	0.3	61	ENE	---	---							
1979	08	0.2	71	ENE	---	---							
Autumn+	12	0.6	198	SSW	270	W							
	16	0.8	205	SSW	203	SSW							
	20	0.7	165	SSE	112	ESE							

* May, 78 only
** Jun., 78; Jul., 78 only
\# Apr., 79; May, 79 only
\+ Nov., 79 only

TABLE 17

Dirunal Wind Pattern
University of Montana Site
Missoula, Montana

	Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		Time	Ave. Wind Speed m/sec	Average Wind Direction Degrees		Prev. Average Wind Direction Degrees		
	Mid	2.5	184	S	112	ESE	Mid	2.7	144	SE	112	ESE	
	04	2.4	180	S	112	ESE	04	3.0	130	SE	112	ESE	
1978	08	2.6	231	SW	270	W	08	2.0	191	S	247	WSW	1978
Spring*	12	3.0	267	W	270	W	12	2.1	242	WSW	270	W	Summer*
	16	3.2	236	SW	270	W	16	2.9	241	WSW	270	W	
	20	2.2	202	SSW	247	WSW	20	1.9	198	SSW	247	WSW	
	Mid	2.9	156	SSE	112	ESE	Mid	3.3	181	S	112	ESE	
	04	3.4	150	SSE	112	ESE	04	3.7	182	S	112	ESE	
1978	08	2.9	166	SSE	112	ESE	08	4.0	180	S	112	ESE	78-79
Autumn+	12	2.2	258	WSW	270	W	12	2.8	223	SW	292	WNW	Winter
	16	2.2	254	WSW	270	W	16	2.5	248	WSW	270	W	
	20	2.2	158	SSE	90	E	20	3.1	195	SSW	270	W	
	Mid	3.0	174	S	90	E	Mid	2.7	139	SE	90	E	
	04	2.8	165	SSE	112	ESE	04	3.1	134	SE	112	ESE	
1979	08	3.0	194	SSW	112	ESE	08	2.4	196	SSW	247	WSW	1979
Spring++	12	3.4	230	SW	270	W	12	2.4	234	SW	270	W	Summer
	16	3.7	245	WSW	270	W	16	2.9	238	WSW	270	W	
	20	3.0	191	S	247	WSW	20	2.2	188	S	247	WSW	
	Mid	2.6	153	SSE	112	ESE							
	04	2.8	148	SSE	112	ESE							
1979	08	2.6	173	S	112	ESE							
Autumn	12	1.8	232	SW	270	W							
	16	2.0	228	SW	270	W							
	20	2.0	158	SSE	90	E							

* May, 78 only
** Jul., 78, Aug., 78 only
\+ Sep., 78, Oct., 78 only
++ Apr., 79, May, 79 only

B. Upper Air Meteorology

Upper air measurements are made through the use of pilot balloons, temperature sondes, and acoustic radar. The pilot balloons and temperature sondes provide information on wind speed, wind direction, temperature profile, mixing heights, and inversion characteristics, while the acoustic radar provides information on atmospheric stability.

Pilot balloon and temperature sonde data were collected at the U.S.F.S. Northern Forest Fire Laboratory (Fire Lab) from June 1978 through November 1979, and pilot balloon data were collected at Lions' Park from October 1978 through November 1979. Acoustic radar data were obtained at the U.S.F.S. Northern Forest Fire Laboratory from December 1977 through November 1979.

Wind Direction and Speed

Percentage frequency summaries of upper level winds are presented in Appendix A and tabulated as monthly values for morning and afternoon periods at various heights above ground level (AGL). Tables 18 and 19 list the prevailing wind direction and speed with height for seasons at the Fire Lab and Lions' Park.

For the Fire Lab, the morning surface wind direction was variable for all seasons. A distinct pattern of morning wind direction was evident from 200 meters (m) AGL to 2000 m AGL, and an east-southeast or southeast flow from 200 m AGL to 1000m AGL was most frequent. A westerly component (west-southwest to northwest) was the flow from 1500m to 2000 m AGL.

The morning wind speeds for the Fire Lab generally increased with height. The following are the lowest and highest monthly average wind speeds:

1978	0.5 m/sec	surface	July, October
	0.4 m/sec	surface	July
1979	17.0 m/sec	1500m AGL	December
	14.3 m/sec	2000m AGL	February

TABLE 18

PREVAILING WIND DIRECTION AND SPEED (M/SEC) WITH HEIGHT
FOR THE U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

MORNING

Height (meters)	1978 Summer		1978 Autumn		1978-1979 Winter		1979 Spring		1979 Summer		1979 Autumn	
Surface	N	0.6	E	1.1	WNW	1.1	SW	1.2	WSW	1.6	N	0.8
100	NNW	2.0	ESE	2.7	SE	3.0	ESE	2.7	NNW	2.4	ESE	1.9
200	SE	2.8	ESE	4.3	ESE	3.6	SE	2.9	ESE	3.9	SE	3.0
300	ESE	4.1	SE	3.1	SE	3.3	SE	3.7	NW*	3.9	SE	3.4
500	ESE	5.8	SE	2.9	SE	4.3	SE	4.9	SE	3.4	SE	3.9
750	ESE	7.5	W	4.0	SE	6.2	SE	6.9	ESE	7.8	SSE	4.2
1000	ESE	7.8	W	7.3	W	12.0	SE	7.9	ESE	11.0	SE	6.5
1500	W	6.7	W	12.0	W	11.5	WSW	10.5	W	8.0	W	8.7
2000	W	7.4	W	17.4	---	----	NW	6.5	WNW	7.5	WNW	10.2

*secondary flow SE 3.7

AFTERNOON

Height (meters)	1978 Summer		1978 Autumn		1978-1979 Winter		1979 Spring		1979 Summer		1979 Autumn	
Surface	W	2.4	W	3.0	W	2.5	SW	4.3	N	2.3	S	2.2
100	W	2.7	NNW	4.4	NNW	3.0	NW	4.3	NNW	6.5	WNW	2.5
200	WNW	3.0	NW	2.5	NNW	5.1	NW	4.4	W	2.2	WNW	3.8
300	NW	3.5	NNW	3.6	NW	9.9	NW	4.6	NNW	5.6	WSW	3.2
500	NW	5.5	NW	7.8	NW	5.3	NW	6.0	NW	6.7	NW	3.6
750	NW	4.7	WNW	6.9	WNW	8.0	WNW	6.2	NW	7.5	NW	3.5
1000	NW	4.5	WNW	7.4	WSW	6.5	WNW	12.1	NW	5.5	W	8.7
1500	W	6.9	W	11.5	W	8.4	WNW	6.6	W	8.1	W	10.8
2000	W	8.2	W	23.0	WNW	13.3	WNW	5.9	W	8.3	WSW	9.5

TABLE 19

PREVAILING WIND DIRECTION AND SPEED (m/sec) WITH HEIGHT
FOR LIONS' PARK MISSOULA, MONTANA

MORNING

Height (meters)	1978 Autumn*	1978-1979 Winter	1979 Spring	1979 Summer	1979 Autumn
Surface	WSW 1.8	WNW 2.1	E 1.5	E 1.1	S 1.2
100	WNW 0.8	SE 1.8	WSW 1.5	S 0.9	SW 1.4
200	SW 3.9	SE 3.4	NE 1.9	SW 0.7	SW 3.0
300	SE 1.5	SE 2.7	WSW 2.4	WSW 3.6	N 1.5
500	ENE 1.8	SE 3.6	SW 3.1	SSE 1.1	SW 2.2
750	S 6.4	SSE 3.6	S 3.7	E 7.1	S 3.0
1000	W 8.7	W 9.6	W 6.9	ESE 5.6	W 5.3
1500	W 12.5	W 13.6	W 12.7	W 8.7	W 6.6
2000	WNW 13.2	WSW 13.3	WSW 8.4	W 7.3	WNW 9.4

AFTERNOON

Height (meters)	1978 Autumn*	1978-1979 Winter	1979 Spring	1979 Summer	1979 Autumn
Surface	WNW 2.1	SSW 2.2	W 5.2	NW 3.1	ENE 3.7
100	WNW 1.9	NW 1.8	WSW 3.9	NNW 2.2	W 1.0
200	WNW 1.7	NW 3.4	WSW 5.8	NW 3.8	NNW 1.1
300	WNW 2.8	WSW 3.0	W 5.8	WNW 3.0	N 2.1
500	WNW 3.3	NW 3.9	NNW 1.6	WNW 3.3	N 2.1
750	W 2.4	W 5.9	W 5.1	W 3.3	WNW 4.0
1000	W 7.7	WSW 8.2	W 7.8	SE 3.6	W 7.4
1500	WSW 11.5	W 9.8	W 9.9	WSW 7.4	W 9.0
2000	W 15.7	W 10.4	W 7.5	WSW 10.3	WSW 10.3

* two months only

The afternoon flow for the Fire Lab was more complex than that for the morning flow. The flow from the surface to 200m AGL generally was in the west to north quadrant. From 300m AGL to 2000m AGL, the flow shifted with height from northwest to west.

The afternoon wind speeds at the surface generally were faster than the morning wind speeds at the surface for the Fire Lab. As with the morning speeds, the afternoon wind speeds generally increased with height. The following are the lowest and highest afternoon monthly average wind speeds:

1978	0.7 m/sec	surface	November
1979	0.2 m/sec	surface	January
1978	12.5 m/sec	2000m AGL	September
	11.9 m/sec	2000m AGL	October

The morning flow for Lions' Park from the surface to 2000m AGL was more complex than the morning flow for the Fire Lab. The Lions' Park flow for the surface to 100m AGL was variable for all seasons, while the flow from 200m AGL to 750m AGL was from southeast to southwest. A westerly component prevailed (west-southwest to west-northwest) from 1000m AGL to 2000m AGL.

The Lions' Park morning wind speeds generally increased with height, and were of the same magnitude as those of the Fire Lab. The following are the lowest and highest monthly average wind speeds:

1978	0.8 m/sec	surface	October
1979	0.5 m/sec	100m AGL	April
1978	13.2 m/sec	2000m AGL	November
1979	15.6 m/sec	2000m AGL	February

The Lions' Park afternoon wind flow exhibited less variability than did the morning flow, and agreement with the Fire Lab afternoon flow was good. The flow from the surface to 2000m AGL generally was from west-southwest to north-northwest, and the flow was somewhat variable from the surface to 300m AGL. The flow from 500m AGL to 2000m AGL shifted with height from west-northwest to west-southwest.

The afternoon wind speeds for Lions' Park also increased with height and were of the same magnitude as the afternoon wind speeds for the Fire Lab. The following are the lowest and highest monthly average wind speeds:

1978	1.4 m/sec	surface	October
1979	0.2 m/sec	surface	January
1978	16.6 m/sec	2000m AGL	November
1979	13.4 m/sec	2000m AGL	February

Temperature Profiles

Data collected from the temperature sondes were tabulated on a monthly basis. Graphs of the average monthly atmospheric temperature profile are contained in Appendix A. These monthly graphs also include barbed notation representing the wind direction and speed with height.

Example:

1000	Northwest (NW 315^{o})	13.5-17.4 m/sec
700	West (W 270^{o})	7.5-13.4 m/sec
400	South (S 180^{o})	3.5 - 7.4 m/sec
100	East-southeast (ESE 112^{o})	Calm - 3.4 m/sec

The Missoula Valley experiences a diurnal pattern of inversions. Due to radiational cooling during the night, an inversion exists in the early morning hours, and dissipates during the day. The spring and summer graphs exemplify this pattern.

The valley experiences extreme inversion situations during the fall and winter, which may persist for several days. During these situations, the inversion does not dissipate, but merely lifts and becomes an elevated inversion. Examples of an elevated afternoon inversion are the January 1979 and November 1979 temperature trace graphs.

Mixing Heights

Mixing height information was computed from the temperature soundings. (The mixing layer is defined as the layer, from the surface upward, through which pollutants can be mixed by convection. The height of the mixing layer is determined graphically by the intersection of the dry adiabatic lapse rate with the actual atmospheric temperature. The dry adiabatic lapse rate is the rate at which a parcel of air will cool as it rises: $9.8^{o}C/Km.$) To determine the morning mixing height, three degrees Celsius were added to the surface temperature. The dry adiabatic lapse rate was followed from the new temperature until the actual temperature trace was intersected.

The afternoon mixing height was determined in the same method as that from the morning, except two degrees Celsius were added to the surface temperature.

The average monthly mixing heights, which are the average of all daily mixing heights, are listed in Table 20. For all months except February 1979, the morning mixing heights are lower than the afternoon mixing heights.

A monthly mixing height was determined from the average monthly temperature graphs (Appendix A). These mixing heights, listed in Table 21, show the same trend as those heights in Table 20. The heights determined graphically are generally lower than the average monthly heights.

The mixing heights expressed in terms of number of occurrences and percentage occurrence are tabulated in Appendix A. For the seventeen months of data, 35 percent were between zero and 100m AGL. A total of 87 percent was between zero and 500m AGL. The winter had 52 percent of mixing heights between 251m and 500m AGL, while the spring had 34 percent of the mixing heights at zero to 100m AGL. During the summer, 43 percent of the mixing heights was between 101m and 250m AGL. The autumn showed 46 percent of the mixing heights between zero and 100m AGL.

TABLE 20

AVERAGE MONTHLY MIXING HEIGHT
U.S.F.S. Northern Forest Fire Laboratory
Missoula, Montana
Values in Meters

Month/Year	Morning	Afternoon
Jul. 1978	150	3920
Aug. 1978	255	925
Sep. 1978	435	1803
Oct. 1978	730	2845
Nov. 1978	285	440
Dec. 1978	260	380
Jan. 1979	240	305
Feb. 1979	480	405
Mar. 1979	245	2320
Apr. 1979	390	2395
May 1979	245	2260
Jun. 1979	335	3755
Jul. 1979	155	1290
Aug. 1979	570	1341
Sep. 1979	85	1425
Oct. 1979	150	1695
Nov. 1979	272	441

TABLE 21

MONTHLY MIXING HEIGHTS AS DETERMINED
FROM AVERAGE MONTHLY TEMPERATURE GRAPHS
U.S.F.S. Northern Forest Fire Laboratory
Missoula, Montana

Month/Year	Morning	Afternoon
Jul. 1978	160	1600
Aug. 1978	170	1820
Sep. 1978	320	1350
Oct. 1978	140	1235
Nov. 1978	145	395
Dec. 1978	185	290
Jan. 1979	230	255
Feb. 1979	320	285
Mar. 1979	190	620
Apr. 1979	360	850
May 1979	150	1480
Jun. 1979	170	None
Jul. 1979	145	740
Aug. 1979	320	1165
Sep. 1979	70	1380
Oct. 1979	80	825
Nov. 1979	180	350

Values in Meters

The mixing height tables in Appendix A show that mixing heights in the afternoon are higher than those in the morning. The seventeen months of data had 27 percent afternoon mixing heights greater than 1500m AGL, with 23 percent between 251m and 500m AGL. The winter showed 48 percent mixing heights between 251m and 500m AGL, while the spring had 46 percent mixing heights greater than 1500m AGL. Forty-two percent of the afternoon mixing heights in summer was greater than 1500m AGL. The autumn had 25 percent between 251m and 500m AGL, with 22 percent greater than 1500m AGL.

Inversions

Temperature sonde data supplied information on inversions, which were categorized by base height, thickness and strength. Inversions were present at least 97 percent of the time for all morning observations, 18 percent of which was surface-based. Inversions were present 87 percent of the time for all afternoon observations, of which only two percent was surface-based.

A seasonal comparison shows that an inversion was present in 99 percent of all morning observations. For afternoon observations, the autumn and winter experienced inversions at least 92 percent of the time, and summer experienced them 72 percent and 64 percent of the time, respectively. The spring had 26 percent surface-based morning inversions, while the winter had 12 percent. The winter and spring experienced 4 percent or less surface-based afternoon inversions, while the summer and autumn experienced no afternoon surface-based inversions.

After having combined the data from the summer months of 1978 and 1979, the most common morning inversion base height was 251m to 500m AGL (20 percent), followed by the surface (18 percent). The majority (over 90 percent) of the morning inversions was one m to 250m AGL. Those morning inversions based at the surface were stronger, Holzworth classification 3 (see Table 5) than those based at 251m to 500m AGL, Holzworth Classification 1.

Summer afternoon inversions had base heights greater than 1000m AGL (1000m to 2000m AGL, 66 percent), and were less intense than morning inversions. The afternoon inversions were one m to 100m thick, Holzworth Classification 1.

The autumn morning inversion's most common base height was the surface (18.0 percent), with 501m to 750m AGL as the second most common base height (17.7 percent). The surface-based inversions were more intense (Holzworth Classification 3 and 101m to 250m thick) than those based at 501m to 750m AGL, one m to 100m thick, and Holzworth Classification 2.

The autumn afternoon inversions were based at 251m to 750m AGL (38 percent), had a thickness of one m to 100m, and were Holzworth Classification 2.

The winter morning inversions were based at 251m to 500m AGL (18 percent), had a thickness of 101m to 250m, and were Holzworth Classification 3.

The winter afternoon inversions were based at 101m to 500m AGL (41 percent), were one m to 250m thick, and were Holzworth Classification 3.

The spring morning inversions were based at the surface (26 percent), with thickness of one m to 250m and Holzworth Classification 3. The spring afternoon inversions had greater base heights (150lm to 200m AGL) than the morning base heights. The thickness for afternoon inversions was the same as that of the morning, but less intense Holzworth Classification 2.

In summary, for all seasons, the mornings experience more total and surface-based inversions than do the afternoons. Except for the autumn, morning inversions have a lower inversion base height and greater inversion thickness than do afternoon inversions. For all seasons, the morning inversions are more intense on the Holzworth Classification scale than are afternoon inversions.

Stability

Atmospheric stability is determined through interpretation of acoustic radar charts. The stability of the surface upward to 100m AGL is coded as unstable, neutral, or stable. (An unstable classification suggests a vertical exchange of air, resulting in low pollution concentrations. A neutral classification indicates a transition from an unstable to stable or stable to unstable atmosphere. A stable classification suggests a limited vertical exchange of air resulting in pollutant accumulation. The stable classification often implies an inversion.)

In addition to the stability classifications, other events were coded. These included formation time, breakup time, base height, top height, and thickness of the stable layer. Cloud height and cover data were used in the computer analysis of the data, which were obtained from observations made at the National Weather Service Office in Missoula.

Table 22 summarizes the frequency of first and second inversions by time of day, and agrees with inversion data collected by the temperature sonde. Morning inversions are present at least 75 percent of the time for all seasons, while afternoon inversions are present in the autumn and winter, but almost non-existent in the spring and summer.

Table 23 summarizes the most common base height and thickness for first inversions by six-hour blocks. The most common base height for 0001-0600 MST and 1801-2400 MST was the surface for all seasons. For 0601-1200 MST, the base generally was the surface for the autumn, winter, and spring, with almost no inversions in the summer during this time block.

The most common first inversion thickness for 0001-0600 MST was 101m-300m for winter, spring and autumn. During the summer, the most common thickness was 301m-500m. For 0601-2400 MST, the most common first inversion

TABLE 22

Percentage Frequency of Occurrence of Periods with Inversions Present From Acoustic Radar

Month	0001-0600 MST		0601-1200 MST		1201-1800 MST		1801-2400 MST	
	First Inversion	Second Inversion	First Inversion	Second Inversion	First Inversion	Second Inversion	First Inversion	Second Inversion
1977 Dec	93.5	3.2	93.5	0.0	83.9	0.0	100.0	0.0
1978 Jan	96.7	0.0	90.3	3.2	71.0	9.7	90.3	3.2
Feb	92.8	0.0	96.4	0.0	66.7	0.0	77.8	0.0
Mar	90.3	0.0	77.4	0.0	22.6	0.0	83.9	0.0
Apr	81.4	0.0	28.8	0.0	0.0	0.0	57.7	0.0
May	86.7	0.0	35.5	3.2	3.2	0.0	80.6	0.0
Jun	89.6	0.0	36.7	0.0	0.0	0.0	73.3	0.0
Jul	89.6	0.0	24.1	0.0	0.0	0.0	100.0	0.0
Aug	86.2	3.2	51.6	0.0	0.0	0.0	86.7	0.0
Sep	85.7	7.1	39.3	7.1	6.9	0.0	92.8	3.6
Oct	83.9	3.2	74.2	0.0	9.7	0.0	93.5	0.0
Nov	76.7	0.0	63.3	3.3	50.0	0.0	86.7	0.0
Dec	96.4	3.2	92.8	3.2	67.8	3.2	89.3	3.2
1979 Jan	90.3	0.0	93.5	0.0	100.0	6.4	96.8	6.4
Feb	85.7	3.6	78.6	0.0	100.0	0.0	96.4	0.0
Mar	90.3	0.0	67.7	0.0	19.4	0.0	93.5	3.2
Apr	82.8	0.0	50.0	0.0	3.3	0.0	93.3	0.0
May	80.6	0.0	25.8	0.0	0.0	0.0	83.9	0.0
Jun								
Jul	100.0	0.0	67.7	0.0	0.0	0.0	90.3	0.0
Aug	90.3	6.4	58.0	9.7	0.0	0.0	83.9	0.0
Sep	93.3	3.3	83.3	0.0	3.3	0.0	90.0	0.0
Oct	100.0	3.2	87.1	6.4	45.2	0.0	96.8	3.2
Nov	90.0	6.7	76.7	6.7	66.7	6.7	90.0	6.7
Dec	96.8	9.7	96.8	16.1	96.8	3.2	100.0	0.0

TABLE 23

Most Common First Inversion
Base Height and Thickness by Time and Month
From Acoustic Radar
Values in Meters

Month	0001-0600 MST Base	0001-0600 MST Thickness	0601-1200 MST Base	0601-1200 MST Thickness	1201-1800 MST Base	1201-1800 MST Thickness	1801-2400 MST Base	1801-2400 MST Thickness
1977 Dec	sfc	101-300	sfc	101-300	sfc	101-300	sfc	101-300
1978 Jan	sfc	101-300	sfc	101-300	sfc	101-300	sfc	101-300
Feb	sfc	301-500	sfc	101-300	sfc	101-300	sfc	101-300
Mar	sfc	301-500	sfc	101-300	sfc	301-500	sfc	101-300
Apr	sfc	101-300	100	101-300	---	-------	sfc	101-300
May	sfc	301-500	sfc	101-300	sfc	101-300	sfc	101-300
Jun	sfc	101-300	200	001-100	---	-------	sfc	101-300
Jul	sfc	301-500	200	001-100	---	-------	sfc	101-300
Aug	sfc	301-500	200	101-300	---	-------	sfc	101-300
Sep	sfc	301-500	200	001-100	200	001-100	sfc	101-300
Oct	sfc	301-500	100	101-300	200	001-100	sfc	101-300
Nov	sfc	101-300	sfc	101-300	sfc	101-300	sfc	101-300
Dec	sfc	101-300	sfc	101-300	sfc	101-300	sfc	101-300
1979 Jan	sfc	101-300	sfc	101-300	sfc	101-300	sfc	101-300
Feb	sfc	101-300	sfc	101-300	sfc	101-300	sfc	101-300
Mar	sfc	101-300	sfc	101-300	sfc	101-300	sfc	101-300
Apr	sfc	101-300	200	101-300	100	001-100	sfc	101-300
May	sfc	101-500	200	101-300	---	-------	sfc	101-300
Jun	sfc	301-500	200	101-300	---	-------	sfc	101-300
Jul	sfc	101-300	100	101-300	---	-------	sfc	101-300
Aug	sfc	301-500	200	101-300	sfc	101-300	sfc	101-300
Sep	sfc	301-500	100	101-300	100	101-300	sfc	101-300
Oct	sfc	301-500	sfc	101-300	sfc	101-300	sfc	101-300
Nov	sfc	301-500	sfc	301-500	sfc	101-300	sfc	101-300
Dec	sfc	301-500	sfc	301-500	sfc	101-300	sfc	101-300

thickness was 101m-300m for all seasons, the exceptions being the spring, with no most common thickness, and the summer, which had no inversions during 1201-1800 MST.

While second inversions were common less than 45 percent of the time (44 percent, 0001-0600 MST; 20 percent, 1201-1800 MST), they generally occurred in the autumn and winter, and had a base height of 400m AGL and a thickness of one m-100m. (See Table 24)

Tables 25 through 29 show the percentage frequency of occurrence of stability classifications. For the period 0001-2400 MST, categories D (neutral) and E (slightly stable) were most common, occurring at least 80 percent during the winter and 30 percent during the summer. Category A (very unstable) occurred only during the spring and summer.

During the nighttime hours 0001-0600 MST, category E (slightly stable) was most common. For all months, only categories D (neutral) through F (moderately stable) occurred.

In the morning hours 0601-1200 MST, the most common category was E (slightly stable). The winter had layers of stability C (slightly unstable) through F (moderately stable); the spring and autumn had layers of stability B (moderately unstable) through F (moderately stable); and the summer months had the most variability with categories A (very unstable) through category F (moderately stable).

During the afternoon hours 1201-1800 MST, the most common stability was C (slightly unstable). For this time period, a seasonal variation is evident with the winter having a most common category of E (slightly stable), and the spring, summer, and autumn indicating category C (slightly unstable). Exceptions are March 1978 and November 1978, which had a most common stability category D (neutral).

The evening hours of 1801-2400 MST showed a pattern similar to the nighttime hours (0001-0600 MST). Only stability categories D (neutral) through F (moderately stable) were recorded, with category E (slightly stable) the most common.

TABLE 24

Most Common Second Inversion
Base Height and Thickness by Time and Month
From Acoustic Radar
Values in Meters

Month	0001-0600 MST Base	Inversion	0601-1200 MST Base	Inversion	1201-1800 MST Base	Inversion	1801-2400 MST Base	Inversi
1977 Dec	500	001-100	---	-------	---	-------	---	-------
1978 Jan	---	-------	600	101-300	300	001-100	300	101-300
Feb	---	-------	---	-------	---	-------	---	-------
Mar	---	-------	---	-------	---	-------	---	-------
Apr	---	-------	---	-------	---	-------	---	-------
May	---	-------	400	001-100	---	-------	---	-------
Jun	---	-------	---	-------	---	-------	---	-------
Jul	---	-------	---	-------	---	-------	---	-------
Aug	200	001-100	---	-------	---	-------	---	-------
Sep	300	001-100	400	001-100	---	-------	400	001-100
Oct	sfc	101-300	---	-------	---	-------	---	-------
Nov	---	-------	400	001-100	---	-------	---	-------
Dec	200	101-300	200	001-100	400	001-100	400	101-300
1979 Jan	---	-------	---	-------	300	001-100	300	001-100
Feb	300	001-100	---	-------	---	-------	---	-------
Mar	---	-------	---	-------	---	-------	400	001-100
Apr	---	-------	---	-------	---	-------	---	-------
May	---	-------	---	-------	---	-------	---	-------
Jun	---	-------	---	-------	---	-------	---	-------
Jul	---	-------	---	-------	---	-------	---	-------
Aug	400	001-100	200	001-100	---	-------	---	-------
Sep	600	001-100	---	-------	---	-------	---	-------
Oct	500	001-100	500	001-100	---	-------	---	-------
Nov	500	001-100	700	001-100	500	001-100	700	101-300
Dec	400	001-100	600	001-100	400	001-100	---	-------

TABLE 25

Percentage Frequency of Occurrence
by Stability Classification
0001-2400 MST

Month	Category A	B	C	D	E	F	U	M
1977 Dec	0.0	0.0	0.0	34.4	56.5	9.1	0.0	0.0
1978 Jan	0.0	0.0	1.1	33.6	56.5	7.5	0.0	1.3
Feb	0.0	0.6	1.2	23.8	63.4	8.0	0.0	3.0
Mar	0.0	1.3	18.8	29.6	36.6	13.7	0.0	0.0
Apr	0.0	1.4	25.0	30.0	25.3	8.1	0.0	10.3
May	0.3	2.2	21.0	36.6	30.9	8.1	0.0	1.0
Jun	3.1	5.8	23.1	30.8	15.6	20.3	0.0	1.4
Jul	3.2	4.3	25.0	23.4	14.0	23.7	0.0	6.5
Aug	0.3	2.2	26.3	23.4	22.8	20.2	0.0	4.8
Sep	0.0	3.1	20.0	29.4	24.4	16.7	0.0	6.4
Oct	0.0	6.5	19.1	21.8	15.9	36.3	0.0	0.5
Nov	0.0	5.3	9.2	32.8	41.7	11.1	0.0	0.0
Dec	0.0	0.0	0.3	23.7	54.3	12.1	0.0	9.7
1979 Jan	0.0	0.0	0.0	19.9	51.1	29.0	0.0	0.0
Feb	0.0	0.0	0.9	33.3	62.8	3.0	0.0	0.0
Mar	0.0	2.2	20.4	24.2	33.3	19.9	0.0	0.0
Apr	0.0	1.1	31.7	26.1	30.8	9.2	0.0	1.1
May	1.1	2.2	31.5	28.2	19.8	17.5	0.0	0.0
77-78 Wtr	0.0	0.2	0.8	30.6	58.8	8.2	0.0	1.4
1978 Spr	0.1	1.6	21.6	32.1	30.9	10.0	0.0	3.8
1978 Sum	2.2	4.1	24.8	25.9	17.5	21.4	0.0	4.2
1978 Aut	0.0	3.9	9.5	26.1	37.3	19.8	0.0	3.4
78-79 Wtr	0.0	0.0	0.4	25.4	55.8	15.1	0.0	3.3
1979 Spr	0.4	1.8	27.8	26.2	27.9	15.6	0.0	0.4

Values in Percentage (of Total Hours)

A-very unstable
B-moderately unstable
C-slightly unstable
D-neutral
E-slightly stable
F-moderately stable
U-unknown
M-missing

TABLE 26

Percentage Frequency of Occurrence
by Stability Classification
0001-0600 MST
Values in Percentage of Total Hours

Month	Category A	B	C	D	E	F	U	M
1977 Dec	0.0	0.0	0.0	25.8	64.5	9.7	0.0	0.0
1978 Jan	0.0	0.0	0.0	24.7	64.5	7.5	0.0	3.2
Feb	0.0	0.0	0.0	15.5	76.2	6.0	0.0	2.4
Mar	0.0	0.0	0.0	23.6	47.3	29.0	0.0	0.0
Apr	0.0	0.0	0.0	20.0	51.1	18.9	0.0	10.0
May	0.0	0.0	0.0	20.4	63.4	12.9	0.0	3.2
Jun	0.0	0.0	0.0	16.7	34.4	45.6	0.0	3.3
Jul	0.0	0.0	0.0	15.0	19.4	59.1	0.0	6.4
Aug	0.0	0.0	0.0	15.0	36.6	41.9	0.0	6.4
Sep	0.0	0.0	0.0	23.3	40.0	30.0	0.0	6.7
Oct	0.0	0.0	0.0	12.9	15.0	72.0	0.0	0.0
Nov	0.0	0.0	0.0	31.1	45.6	23.3	0.0	0.0
Dec	0.0	0.0	0.0	16.1	63.4	10.8	0.0	9.7
1979 Jan	0.0	0.0	0.0	21.5	44.1	34.4	0.0	0.0
Feb	0.0	0.0	0.0	34.5	59.5	6.0	0.0	0.0
Mar	0.0	0.0	0.0	16.1	47.3	36.6	0.0	0.0
Apr	0.0	0.0	0.0	21.1	56.7	18.9	0.0	3.3
May	0.0	0.0	0.0	18.3	39.8	41.9	0.0	0.0
77-78 Wtr	0.0	0.0	0.0	22.2	68.1	7.8	0.0	1.8
1978 Spr	0.0	0.0	0.0	21.4	54.0	20.3	0.0	4.3
1978 Sum	0.0	0.0	0.0	15.6	30.1	48.9	0.0	5.4
1978 Aut	0.0	0.0	0.0	22.3	33.3	42.1	0.0	2.2
78-79 Wtr	0.0	0.0	0.0	23.7	55.6	17.4	0.0	3.3
1979 Spr	0.0	0.0	0.0	18.5	47.8	32.6	0.0	1.1

A-very unstable
B-moderately unstable
C-slightly unstable
D-neutral
E-slightly stable
F-moderately stable
U-unknown
M-missing

TABLE 27

Percentage Frequency of Occurrence
by Stability Classification
0601-1200 MST
Values in Percentage of Total Hours

Month	Category A	B	C	D	E	F	U	M
1977 Dec	0.0	0.0	0.0	44.1	49.5	6.4	0.0	0.0
1978 Jan	0.0	0.0	0.0	38.7	50.5	8.6	0.0	2.2
Feb	0.0	0.0	1.2	22.6	67.8	8.3	0.0	0.0
Mar	0.0	4.3	34.4	24.7	36.6	0.0	0.0	0.0
Apr	0.0	1.1	43.3	28.9	14.4	3.3	0.0	8.9
May	1.1	6.4	32.2	46.2	11.8	2.2	0.0	0.0
Jun	10.0	18.9	35.6	32.2	0.0	2.2	0.0	1.1
Jul	12.9	7.5	32.2	34.4	3.2	3.2	0.0	6.4
Aug	1.1	8.6	30.1	34.4	12.9	6.4	0.0	6.4
Sep	0.0	7.8	32.2	41.1	7.8	4.4	0.0	6.7
Oct	0.0	12.9	24.7	33.3	10.8	17.2	0.0	1.1
Nov	0.0	14.4	15.6	30.0	35.6	4.4	0.0	0.0
Dec	0.0	0.0	0.0	19.4	59.1	11.8	0.0	9.8
1979 Jan	0.0	0.0	0.0	18.3	59.1	22.6	0.0	0.0
Feb	0.0	0.0	1.2	34.5	61.9	2.4	0.0	0.0
Mar	0.0	5.4	26.9	35.5	19.4	12.9	0.0	0.0
Apr	0.0	4.4	47.8	32.2	12.2	2.2	0.0	1.1
May	4.3	7.5	44.1	40.9	3.2	0.0	0.0	0.0
77-78 Wtr	0.0	0.0	3.7	35.6	55.6	7.8	0.0	0.7
1978 Spr	0.4	4.1	41.7	38.1	9.9	2.1	0.0	3.3
1978 Sum	8.0	11.6	32.6	33.7	5.4	4.1	0.0	4.7
1978 Aut	0.0	11.7	24.2	34.8	17.9	8.8	0.0	2.6
78-19 Wtr	0.0	0.0	0.4	23.7	60.0	12.6	0.0	3.3
1979 Spr	1.4	5.8	39.5	36.2	11.6	5.1	0.0	0.4

A-very unstable
B-moderately unstable
C-slightly unstable
D-neutral
E-slightly stable
F-moderately stable
U-unknown
M-missing

TABLE 28

Percentage Frequency of Occurrence
by Stability Classification
1201-1800 MST
Values in Percentage of Total Hours

Month	Category A	B	C	D	E	F	U	M
1977 Dec	0.0	0.0	0.0	38.7	53.8	7.5	0.0	0.0
1978 Jan	0.0	0.0	4.3	38.7	50.5	6.4	0.0	0.0
Feb	0.0	2.4	3.6	29.8	59.5	1.2	0.0	3.6
Mar	0.0	1.1	40.9	44.1	14.0	0.0	0.0	0.0
Apr	0.0	4.4	56.7	30.0	0.0	0.0	0.0	8.9
May	0.0	2.2	51.6	44.1	2.2	0.0	0.0	0.0
Jun	2.2	4.4	56.7	35.6	0.0	0.0	0.0	1.1
Jul	0.0	8.6	68.8	14.0	2.2	0.0	0.0	6.4
Aug	0.0	0.0	75.3	19.4	2.2	0.0	0.0	3.2
Sep	0.0	4.4	47.8	36.7	5.6	0.0	0.0	5.6
Oct	0.0	12.9	51.6	30.1	3.2	1.1	0.0	1.1
Nov	0.0	6.7	21.1	46.7	24.4	1.1	0.0	0.0
Dec	0.0	0.0	1.1	36.6	43.0	9.7	0.0	9.7
1979 Jan	0.0	0.0	0.0	21.6	52.7	25.8	0.0	0.0
Feb	0.0	0.0	2.4	42.8	53.6	1.1	0.0	0.0
Mar	0.0	3.2	55.9	21.6	15.0	4.3	0.0	0.0
Apr	0.0	0.0	78.9	18.9	2.2	0.0	0.0	0.0
May	0.0	1.1	81.7	17.2	0.0	0.0	0.0	0.0
77-78 Wtr	0.0	0.7	2.6	35.9	54.4	5.2	0.0	1.1
1978 Spr	0.0	2.5	49.6	39.4	5.4	0.0	0.0	2.9
1978 Sum	0.7	4.3	67.0	22.8	1.4	0.0	0.0	3.4
1978 Aut	0.0	8.0	40.3	37.7	11.0	0.7	0.0	2.2
78-79 Wtr	0.0	0.0	1.1	33.3	49.6	12.6	0.0	3.3
1979 Spr	0.0	1.4	72.1	19.2	5.8	1.4	0.0	0.0

A-very unstable
B-moderately unstable
C-slightly unstable
D-neutral
E-slightly stable
F-moderately stable
U-unknown
M-missing

TABLE 29

Percentage Frequency of Occurrence
by Stability Classification
1801-2400 MST
Values in Percentage of Total Hours

Month	Category A	B	C	D	E	F	U	M
1977 Dec	0.0	0.0	0.0	24.7	62.4	12.9	0.0	0.0
1978 Jan	0.0	0.0	0.0	29.0	63.4	7.5	0.0	0.0
Feb	0.0	0.0	0.0	27.4	50.0	16.7	0.0	6.0
Mar	0.0	0.0	0.0	25.8	48.4	25.8	0.0	0.0
Apr	0.0	0.0	0.0	41.1	35.6	10.0	0.0	13.3
May	0.0	0.0	0.0	35.5	46.2	17.2	0.0	1.1
Jun	0.0	0.0	0.0	38.9	27.8	33.3	0.0	0.0
Jul	0.0	0.0	0.0	29.0	32.2	32.2	0.0	6.4
Aug	0.0	0.0	0.0	24.7	37.6	34.4	0.0	3.2
Sep	0.0	0.0	0.0	16.7	44.4	32.2	0.0	6.7
Oct	0.0	0.0	0.0	10.8	34.4	54.8	0.0	0.0
Nov	0.0	0.0	0.0	23.3	61.1	15.6	0.0	0.0
Dec	0.0	0.0	0.0	21.6	52.7	16.1	0.0	9.7
1979 Jan	0.0	0.0	0.0	18.3	48.4	33.3	0.0	0.0
Feb	0.0	0.0	0.0	21.4	76.2	2.4	0.0	0.0
Mar	0.0	0.0	0.0	22.6	51.6	25.8	0.0	0.0
Apr	0.0	0.0	0.0	32.2	52.2	15.6	0.0	0.0
May	0.0	0.0	0.0	36.6	35.5	28.0	0.0	0.0
77-78 Wtr	0.0	0.0	0.0	27.0	58.9	12.2	0.0	1.8
1978 Spr	0.0	0.0	0.0	34.0	43.4	17.8	0.0	4.7
1978 Sum	0.0	0.0	0.0	30.8	32.6	33.3	0.0	3.3
1978 Aut	0.0	0.0	0.0	16.8	46.5	34.4	0.0	2.2
78-79 Wtr	0.0	0.0	0.0	20.4	58.5	17.8	0.0	3.3
1979 Spr	0.0	0.0	0.0	30.4	46.4	23.2	0.0	0.0

A-very unstable
B-moderately unstable
C-slightly unstable
D-neutral
E-slightly stable
F-moderately stable
U-unknown
M-missing

TABLE 30

Average Formation and Lifting Time
for the Stable Layer
From Acoustic Radar

Month/Year	Average Formation Time (MST)	Average Lifting Time (MST)
Dec., 1977		
Jan., 1978		
Feb., 1978		
Mar., 1978	1925	0930
Apr., 1978	1950	0835
May , 1978	1950	0755
Jun., 1978	2020	0630
Jul., 1978	1955	0645
Aug., 1978	1905	0810
Sep., 1978	1905	0840
Oct., 1978	1830	0840
Nov., 1978	1830	0925
Dec., 1978	Inversion present all month	
Jan., 1979	Inversion present all month	
Feb., 1979	Inversion present all month	
Mar., 1979	1830	0905
Apr., 1979	1900	0705
May , 1979	1945	0645
Jun., 1979		
Jul., 1979		
Aug., 1979	1900	0710
Sep., 1979	1800	0820
Oct., 1979	1750	0812
Nov., 1979	1712	0905
Dec., 1979	Inversion present all month	
Jan., 1980		
Feb., 1980	1654	1002

APPENDIX A

DATA SUMMARIES

WIND ROSE PRINTOUTS

AND

WIND ROSE DIAGRAMS

AVERAGE MONTHLY TEMPERATURE (°C)

U.S.F.S. NORTHERN FOREST FIRE LAB

SITE: MISSOULA, MONTANA

YEAR: 1978

TIME (AM OR PM) : PM

LEVEL (METERS)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SPR	SUM	AUT	WTR	ANNUAL
SFC							24.3	24.4	18.4	14.1	-0.4	-5.8					
54							23.8	23.8	17.8	12.0	-0.6	-6.6					
107							23.2	23.0	17.3	11.5	-1.0	-6.7					
161							22.6	22.7	16.6	11.0	-1.3	-6.8					
214							22.0	22.3	15.9	10.6	-1.4	-6.9					
268							21.7	21.6	15.1	10.1	-1.3	-6.8					
321							21.3	21.0	14.8	9.6	-1.4	-6.6					
375							21.0	20.4	14.3	9.3	-1.5	-6.6					
428							20.6	20.1	13.8	9.2	-1.4	-6.7					
482							20.1	18.9	13.4	8.8	-1.7	-7.1					
535							19.6	18.2	12.9	8.3	-1.5	-7.4					
642							18.5	16.9	12.4	7.6	-1.9	-8.0					
749							17.3	15.5	10.6	7.0	-2.2	-8.5					
856							16.0	14.8	11.1	6.2	-2.1	-9.3					
963							14.7	13.9	10.3	5.6	-2.2	-9.7					
1070							13.7	13.2	9.4	5.2	-2.3	-10.3					
1177							13.0	12.4	8.1	3.8	-2.0	-10.8					
1284							12.2	11.6	7.6	4.0	-2.4	-11.4					
1391							11.4	10.6	6.9	3.2	-2.9	-12.2					
1498							10.7	9.9	6.1	2.8	-3.3	-12.8					
1605							10.3	9.2	5.4	2.1	-3.3	-13.7					
1712							9.9	8.7	4.7	1.2	-3.6	-14.4					
1819							9.3	8.4	4.5	0.4	-4.0	-15.2					
1926							8.8	8.0	4.4	-0.4	-4.4	-16.0					
2033							8.4	7.4	3.8	-0.3	-4.7	-16.6					
2140							7.2	5.7	3.9	-1.7	-5.3	-17.1					

AVERAGE MONTHLY TEMPERATURE (°C)

SITE: U.S.F.S. Northern Fire Lab. Missoula

YEAR: 1978

TIME (AM OR PM) : AM

LEVEL (METRE)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	SPR	SUM	AUT	WTR	ANNUAL
SFC							9.7	8.0	7.3	-0.5	-5.9	-8.3					
54							10.6	8.8	7.4	0.2	-5.1	-7.6					
107							10.6	9.2	7.4	0.9	-4.5	-7.2					
161							10.8	9.2	7.4	1.2	-4.3	-7.1					
214							12.1	9.4	7.3	1.5	-4.2	-7.2					
268							12.8	9.4	7.2	1.8	-4.2	-7.2					
321							12.2	9.5	7.1	2.0	-4.0	-7.2					
375							12.4	9.5	7.0	2.2	-3.9	-7.2					
428							12.5	9.6	6.8	2.2	-3.6	-6.6					
482							12.8	9.7	6.7	2.4	-3.5	-6.4					
535							12.5	9.8	6.9	2.4	-3.4	-6.8					
642							12.3	9.6	6.8	2.6	-3.2	-6.9					
749							12.3	9.3	6.7	2.8	-3.4	-7.4					
856							12.4	9.1	6.4	2.6	-3.6	-7.2					
963							12.4	8.7	5.9	2.4	-3.5	-7.6					
1070							12.1	8.5	5.6	1.8	-3.2	-7.8					
1177							11.7	8.1	5.1	1.4	-3.7	-8.2					
1284							11.3	7.8	4.8	0.9	-4.1	-8.5					
1391							10.7	7.4	4.3	0.5	-4.3	-9.0					
1498							10.2	7.0	3.8	0.1	-4.7	-9.6					
1605							9.7	6.6	3.1	-0.5	-5.1	-10.5					
1712							9.7	6.2	2.7	-0.9	-5.4	-11.2					
1819							9.2	5.6	2.0	-1.2	-5.5	-11.8					
1926							8.6	4.9	1.1	-1.4	-6.1	-12.4					
2033							9.1	5.2	0.2	-1.8	-6.4	-13.0					
2140							6.8	2.5	-0.8	-2.2	-7.0	-13.4					

AVERAGE MONTHLY TEMPERATURE (°C)

Missoula

SITE: U.S.F.S. Northern Fire Lab.

YEAR: 1979

TIME (AM OR PM): AM (Morning)

(LEVEL (METERS) asl	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	~~SPR~~	~~SUM~~	~~AUT~~	~~WIN~~	~~ANNUAL~~
	-16.9	-4.6	-2.0	1.1	7.4	9.9	11.9	14.1	5.1	1.6	-6.8						
54	-16.7	-4.6	-0.9	1.3	5.7	11.0	12.8	14.0	7.3	3.5	-5.9						
107	-16.6	-4.6	-0.8	1.3	5.8	11.2	13.4	14.0	8.4	4.1	-5.7						
161	-16.4	-4.7	-0.7	1.1	5.9	11.3	13.6	13.9	8.7	4.1	-5.6						
214	-16.2	-4.8	-0.9	1.0	6.0	11.1	13.8	13.9	8.9	4.3	-5.5						
268	-14.9	-4.7	-0.2	0.7	6.2	11.3	14.0	14.0	9.0	4.5	-5.4						
321	-14.4	-4.7	-0.3	0.6	6.1	11.2	14.1	14.0	9.1	4.6	-5.4						
375	-15.3	-4.7	-1.2	0.6	5.9	11.3	14.4	13.7	9.2	4.8	-5.4						
428	-13.9	-4.3	-0.7	0.6	5.8	11.3	14.5	13.6	9.6	4.9	-5.3						
482	-13.8	-4.5	-0.7	0.5	5.7	11.1	14.6	13.4	9.9	5.0	-5.2						
535	-14.8	-4.6	-1.3	0.3	5.6	11.2	14.6	13.5	10.2	5.1	-5.2						
642	-14.2	-4.6	-0.8	-0.1	5.3	11.0	14.5	13.2	10.1	5.3	-5.1						
749	-13.6	-5.0	-1.8	-0.6	4.8	10.7	14.3	12.8	10.3	5.2	-5.0						
856	-12.9	-5.5	-2.3	-1.0	4.4	10.6	14.1	12.5	10.6	5.0	-4.9						
963	-12.4	-6.5	-2.8	-1.4	3.7	10.3	13.8	12.3	10.7	5.1	-4.8						
1070	-12.4	-6.6	-2.4	-1.9	3.0	10.1	13.3	12.0	10.6	4.9	-5.0						
1177	-12.1	-6.8	-3.5	-2.5	2.6	9.4	12.7	11.6	10.4	4.7	-4.4						
1284	-11.6	-7.5	-4.1	-3.1	2.1	8.7	12.1	11.2	10.4	4.4	-4.4						
1391	-11.7	-8.1	-4.8	-3.5	1.5	8.0	11.6	10.7	10.3	4.0	-4.9						
1498	-11.4	-8.7	-5.4	-4.0	0.8	7.3	11.0	10.1	9.8	3.6	-5.2						
1605	-11.7	-9.2	-6.0	-4.6	0.0	6.6	10.4	9.5	9.3	3.1	-5.5						
1712	-11.8	-9.9	-6.8	-5.7	-0.8	6.0	9.9	9.0	9.0	2.8	-5.8						
1819	-11.8	-10.3	-7.4	-5.9	-1.4	5.2	9.4	8.4	8.7	2.3	-6.1						
1926	-12.3	-10.7	-8.1														
2033	-12.2	-11.0	-8.6														
2140	-11.5	-11.6	-9.3														

Missoula

AVERAGE MONTHLY TEMPERATURE (°C)

SITE: U.S.F.S. Northern Fire Lab

YEAR: 1979

TIME (AM OR PM): PM (Afternoon)

LEVEL (METERS)	JAN*	FEB*	MAR	APR*	MAY	JUN	JUL	AUG	SEP	OCT*	NOV	DEC	~~SPR~~	~~SUM~~	~~FALL~~	~~WTR~~	ANNUAL
SFC	-10.6	0.2	6.4	11.3	16.2	21.4	28.0	25.8	23.9	14.1	-0.8						
54	-11.3	-0.7	5.8								-2.1						
107	-11.6	-0.7	5.3								-2.6						
161	-11.4	-0.6	4.9	8.8	13.4	18.9	25.4	22.7	20.5	11.5	-2.7						
214	-11.2	-0.5	4.5								-2.6						
268	-11.0	-0.5	4.1								-2.5						
321	-10.8	-0.7	3.8								-2.3						
375	-10.6	-0.8	3.5								-2.2						
428	-10.4	-0.8	3.3								-2.0						
482	-10.0	-0.9	3.2								-1.9						
535	-9.6	-1.2	2.8								-2.1						
642	-9.6	-1.8	2.2								-2.1						
749	-9.2	-2.4	1.5	5.0	9.1	14.2	21.2	18.9	16.0	8.4	-1.9						
856	-9.5	-2.8	-0.6								-1.9						
963	-9.3	-3.0	-0.5								-1.9						
1070	-9.7	-4.0	-1.3	2.8	6.5	11.6	19.3	16.7	14.2	6.7	-2.1						
1177	-10.3	-4.9	-1.7								-2.6						
1284	-10.8	-5.8	-2.7								-3.0						
1391	-11.4	-6.6	-3.7								-3.3						
1498	-12.0	-7.5	-4.4								-3.7						
1605	-12.5	-8.3	-4.8								-4.1						
1712	-12.7	-9.1	-5.2								-4.4						
1819	-12.8	-9.7	-6.0	-2.1	1.5	5.6	13.1	12.5	10.3	2.1	-4.7						
1926	-12.4	-10.6	-6.5														
2033	-12.7	-11.2	-5.9														
2140	-12.9	-11.7	-6.1														

* used Bal *1 & 2, not enough data to compute separate tables

AVERAGE MONTHLY TEMPERATURE (°C)

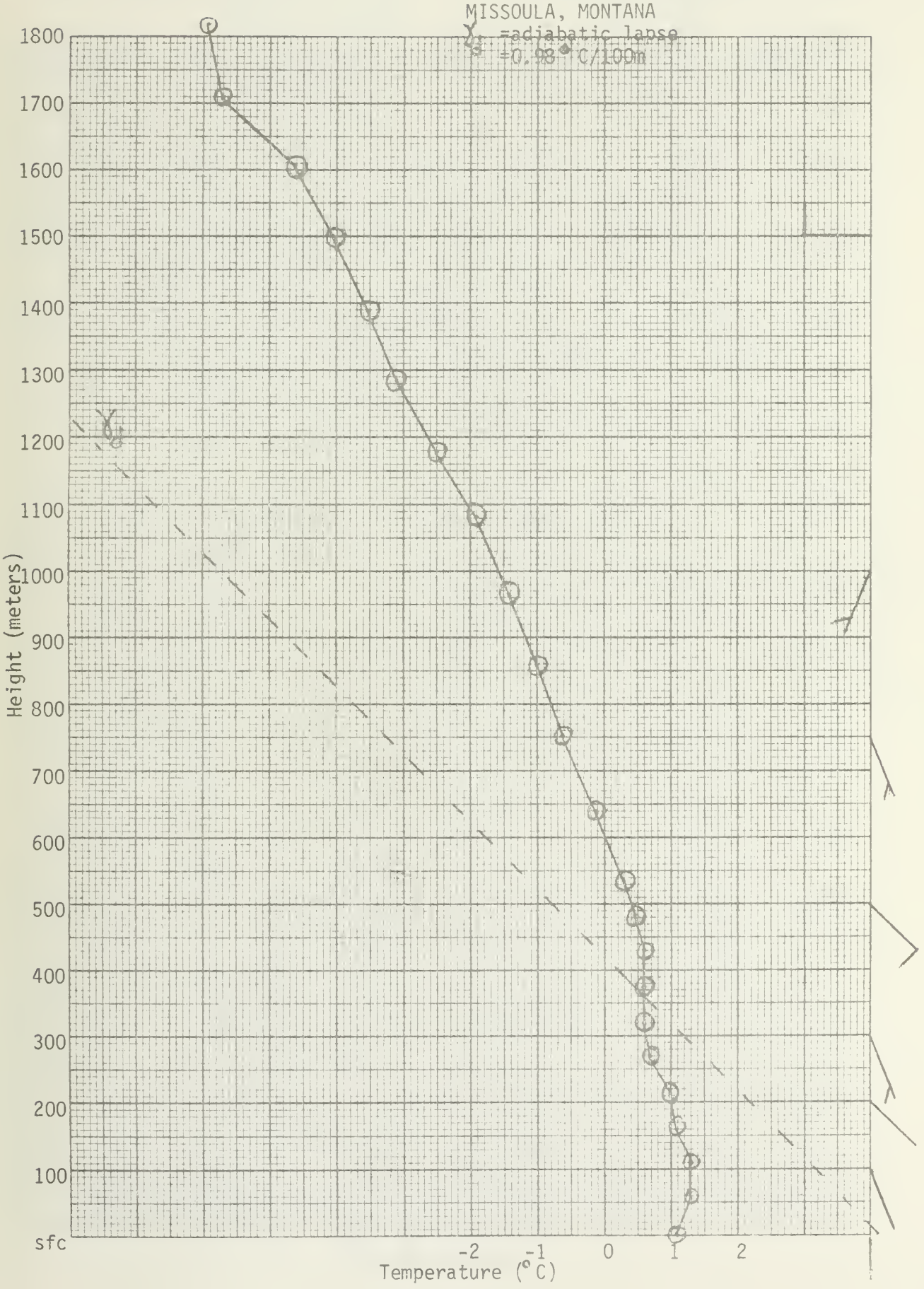
U.S.F.S. NORTHERN FOREST FIRE LAB

SITE: MISSOULA, MONTANA

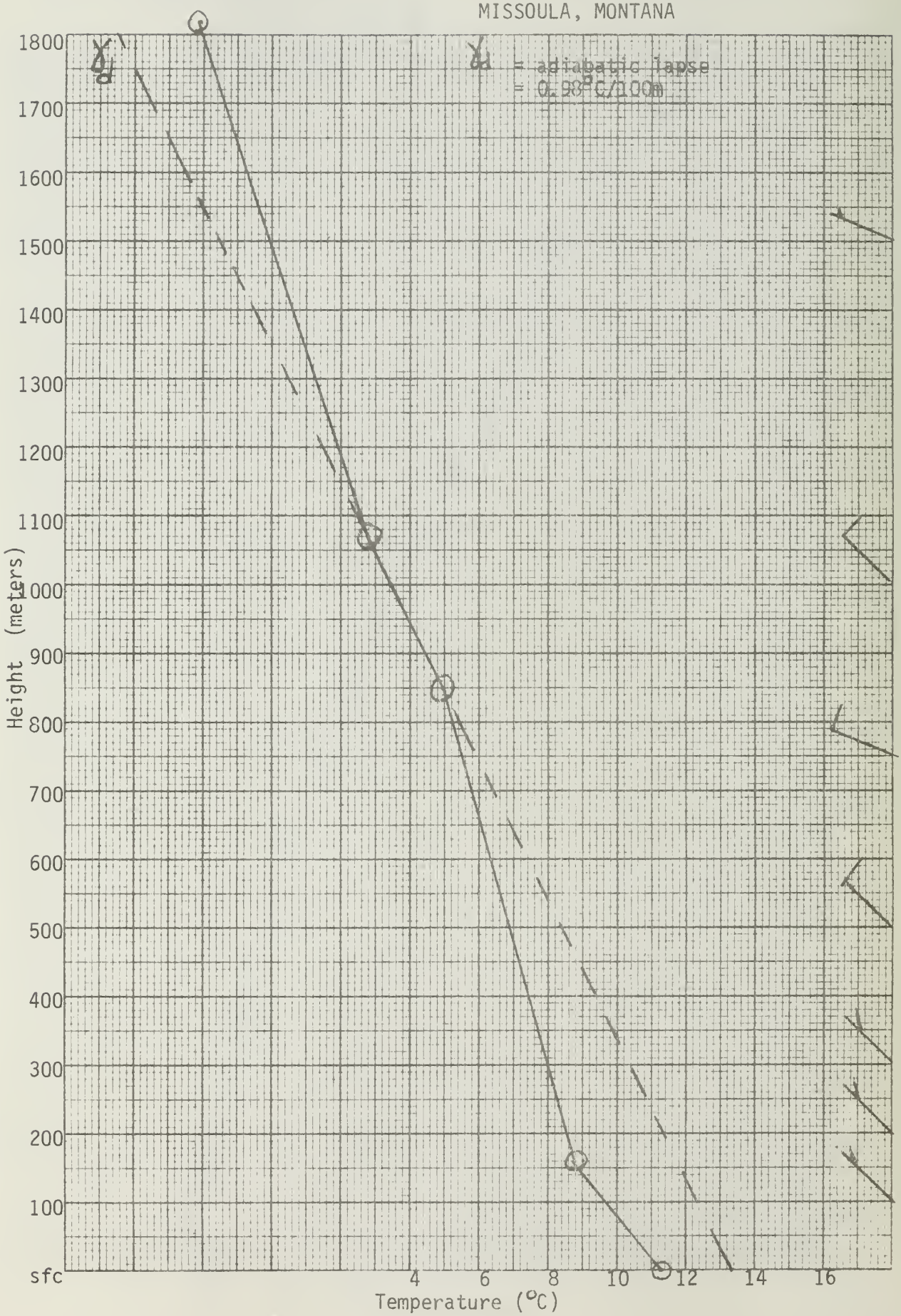
YEAR: 1979

TIME (AM OR PM) : PM

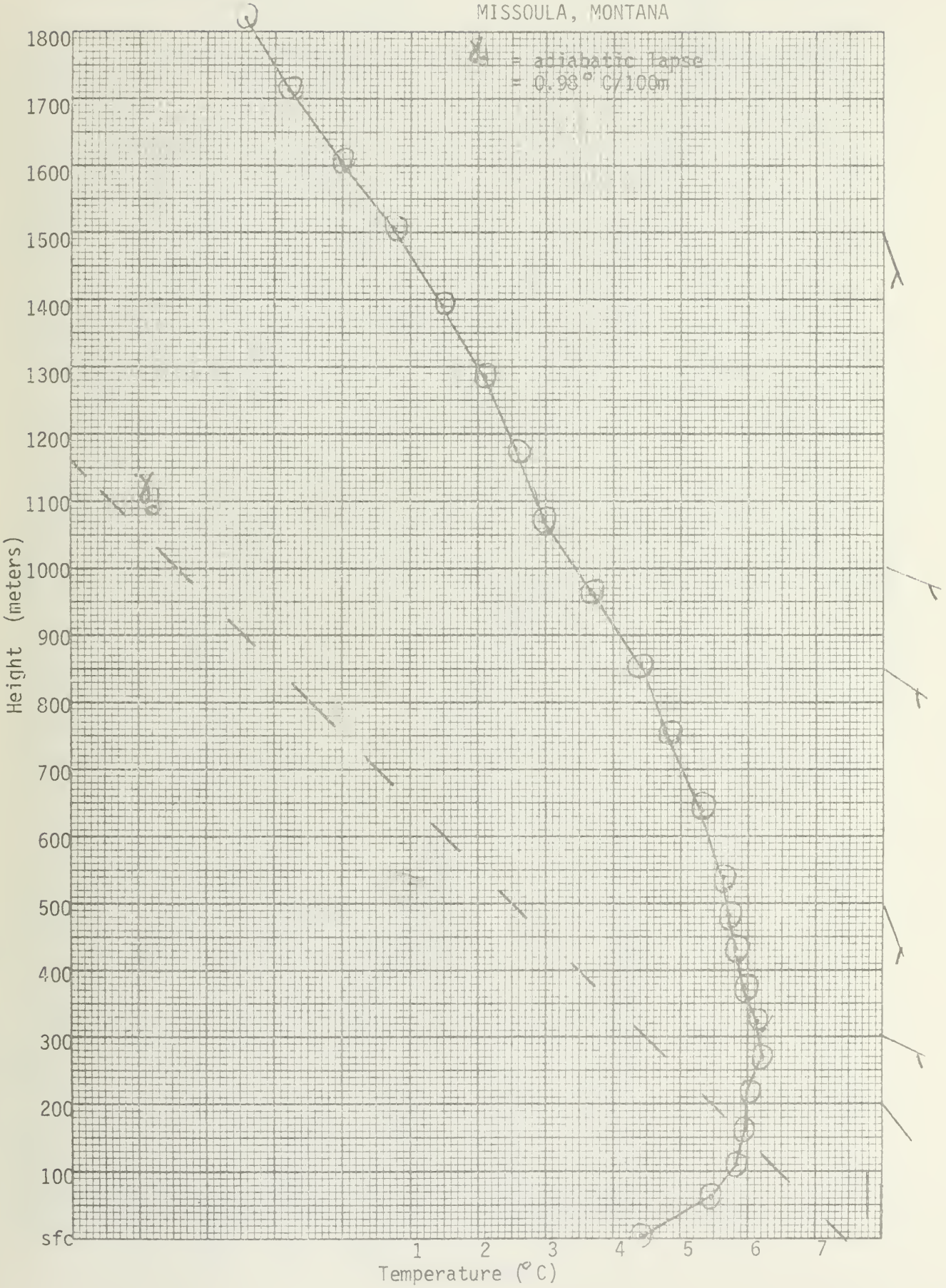
LEVEL (METERS)	JAN	FEB	MAR	APR*	MAY	JUN	JUL	AUG	SEP	OCT*	NOV	DEC	SPR	SUM	AUT	WTR	ANNUAL
SFC				11.3	16.2	21.4	28.0	25.8	23.9	14.1							
83					14.1	19.9	26.5	23.5	21.5								
165				8.8	13.4	18.9	25.4	22.7	20.5	11.5							
248					12.4	18.1	24.4	22.2	19.7								
330					11.8	17.4	23.7	21.6	18.9								
413					11.1	16.7	23.4	21.0	18.2								
496					10.4	16.0	23.0	20.4	17.1								
578					9.7	15.4	22.4	19.9	16.9								
661					9.1	14.9	21.6	19.4	16.4								
744				5.0	9.1	14.2	21.2	18.9	16.0	8.4							
909					7.2	12.8	20.2	17.8	15.2								
1074				2.8	6.5	11.6	19.3	16.7	14.2	6.7							
1322					4.5	3.9	17.6	15.7	12.7								
1570					3.3	7.3	15.5	14.1	11.6								
1818				-2.1	1.8	5.6	13.1	12.5	10.3	2.1							


APRIL 1979
MORNING
AVE. MONTHLY TEMP. TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA
γ_d =adiabatic lapse
= ±0.98° C/100m
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sfc
Height (meters)
-2
-1
0
1
2
Temperature (°C)

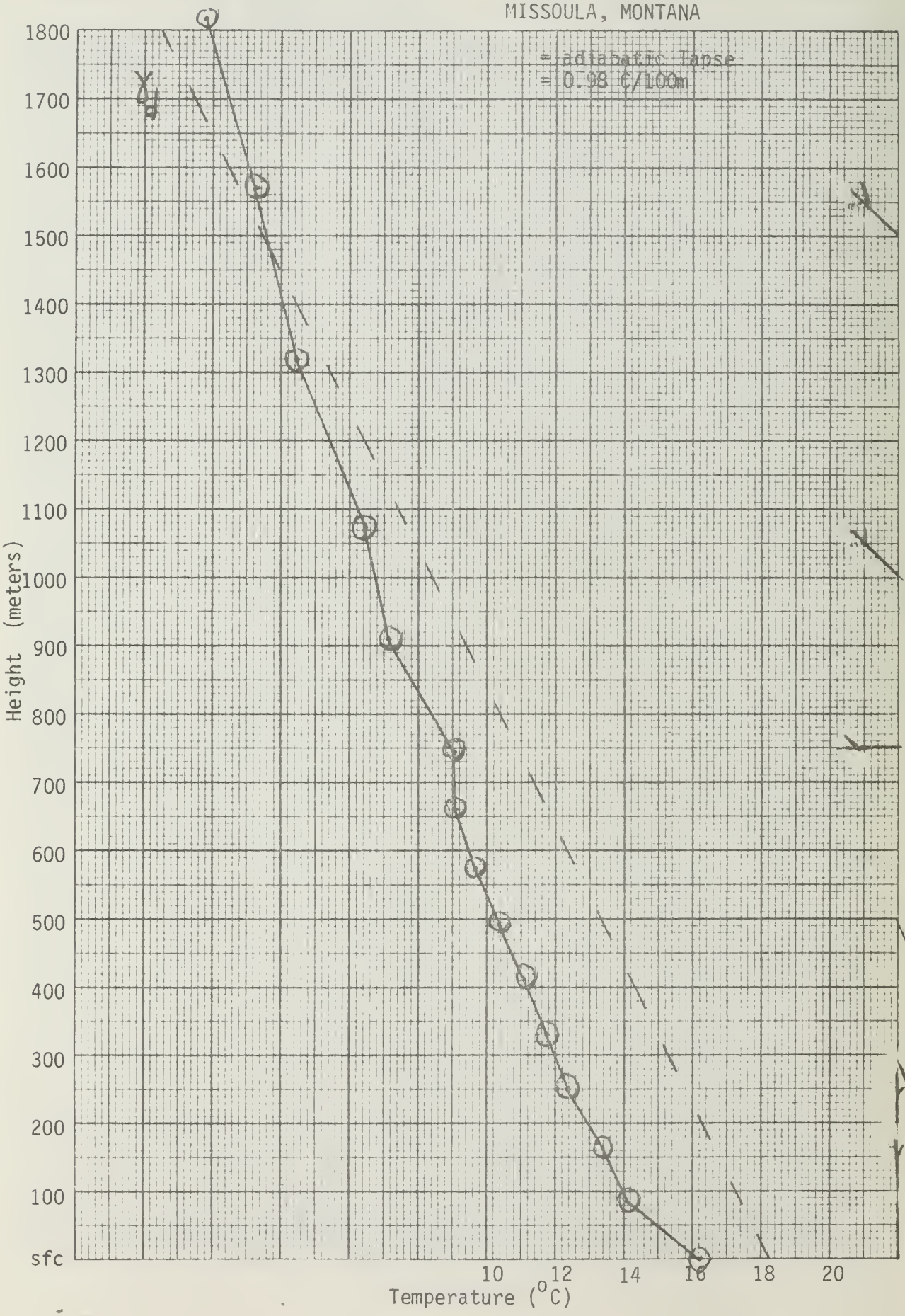
APRIL 1979
AFTERNOON
AVE. MONTHLY TEMP. TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA



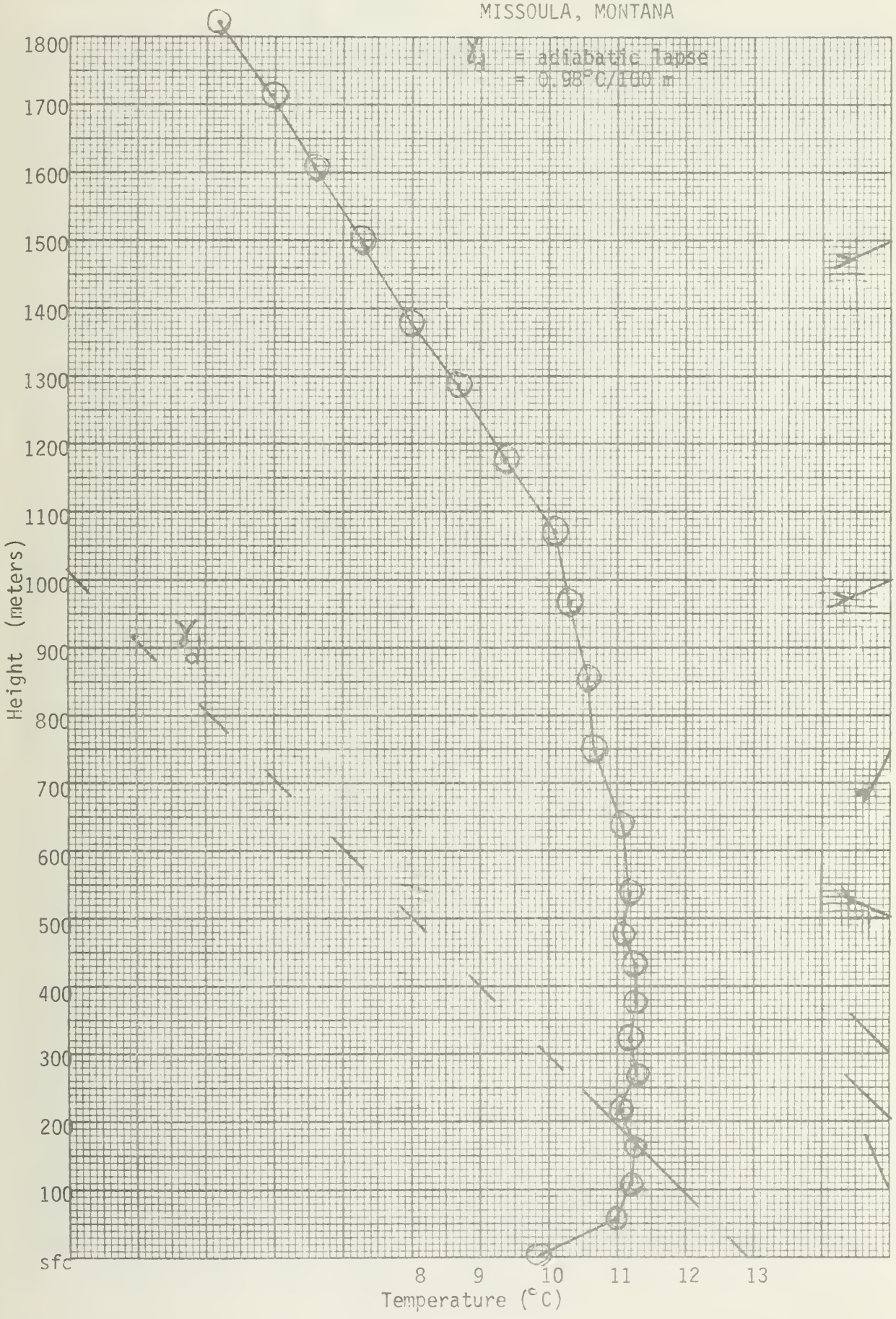
CLEARPRINT PAPER CO NO. C310 20 DIVISIONS PER INCH BOTH WAYS 120 BY 180 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1015


MAY 1979
MORNING
AVE. MONTHLY TEMP. TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA
= adiabatic lapse
= 0.98° C/100m
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sfc
Height (meters)
1
2
3
4
5
6
7
Temperature (°C)

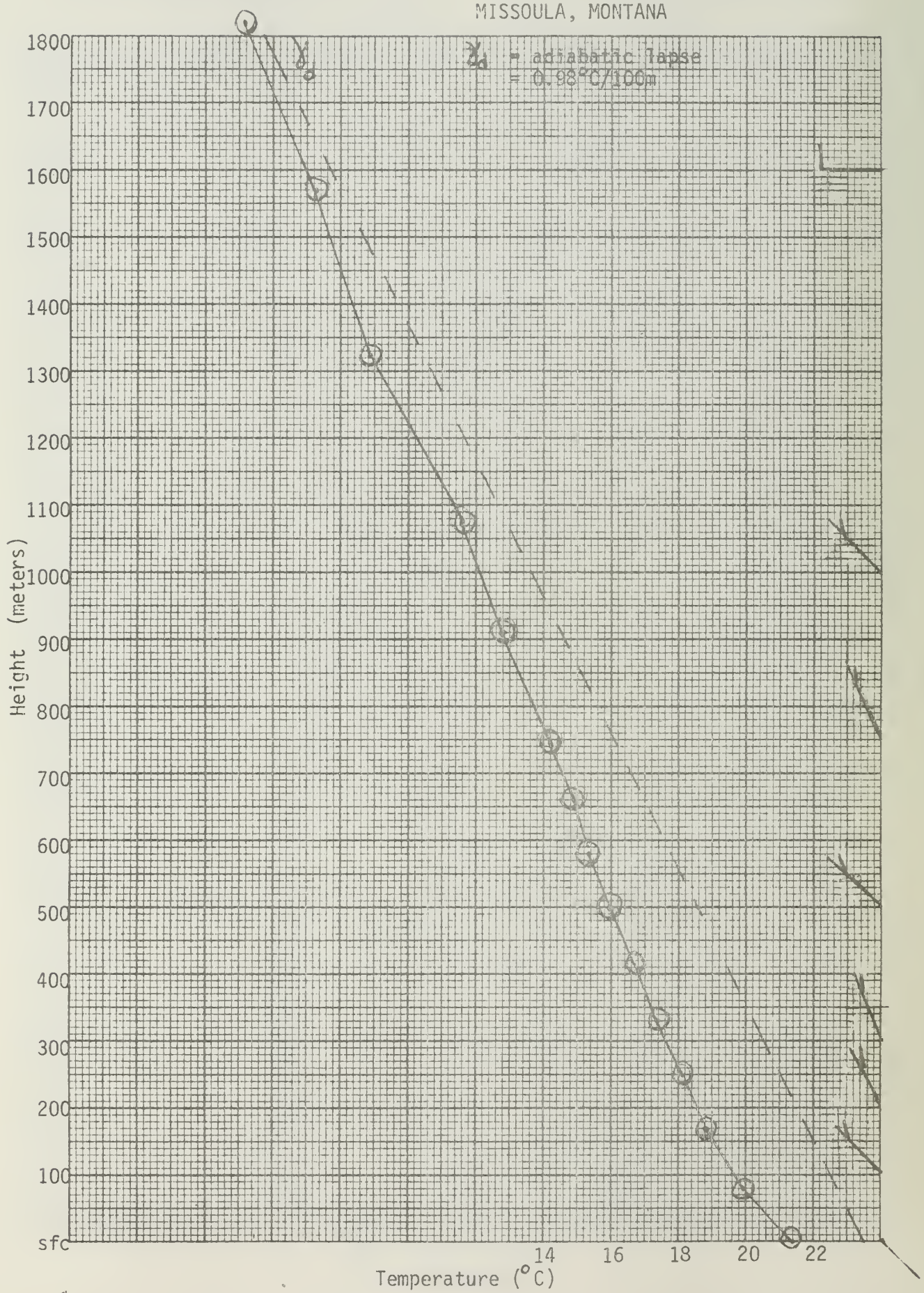
MAY 1979
AFTERNOON
AVE. MONTHLY TEMP. TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA



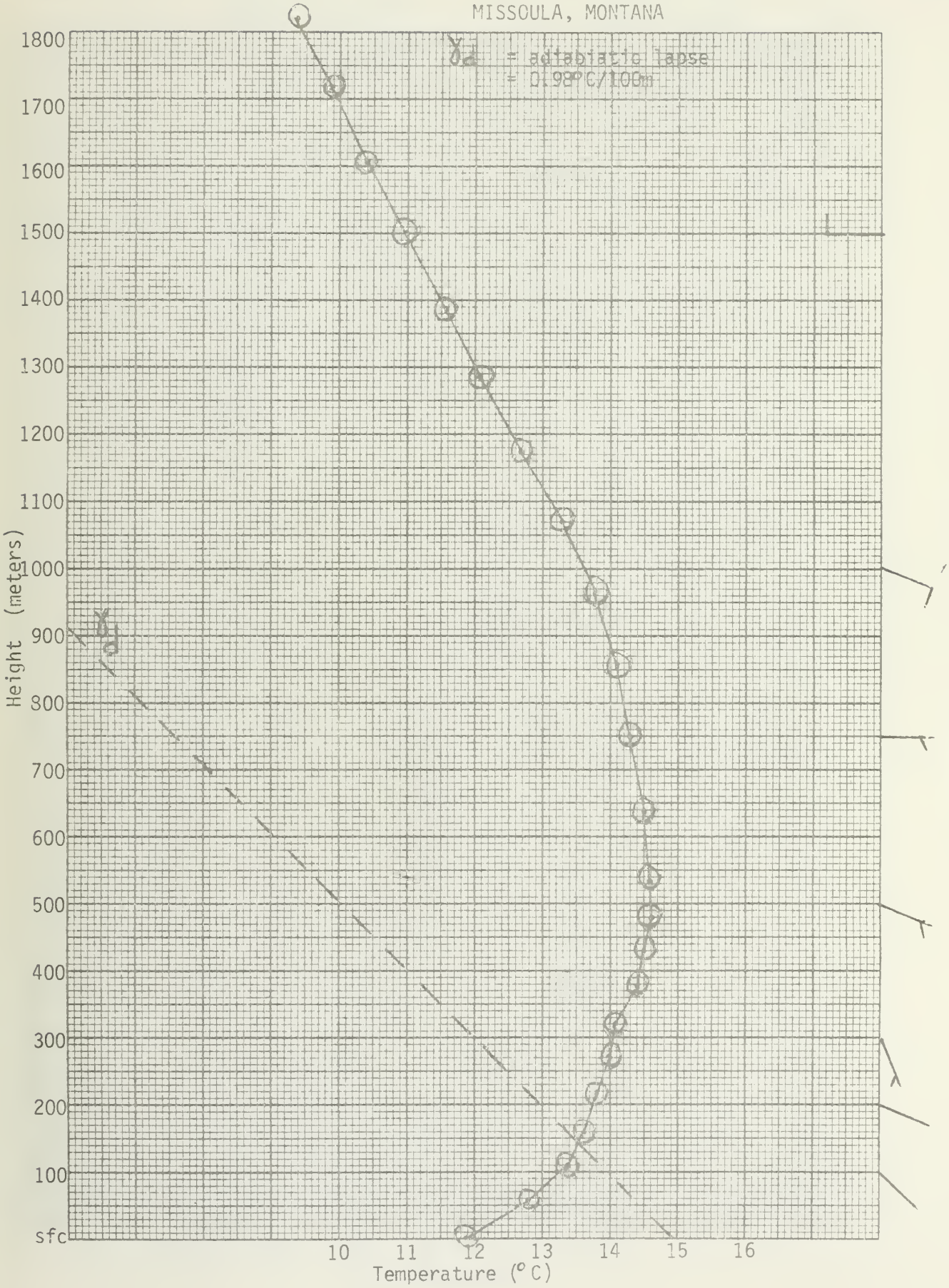
JUNE 1979
MORNING
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA



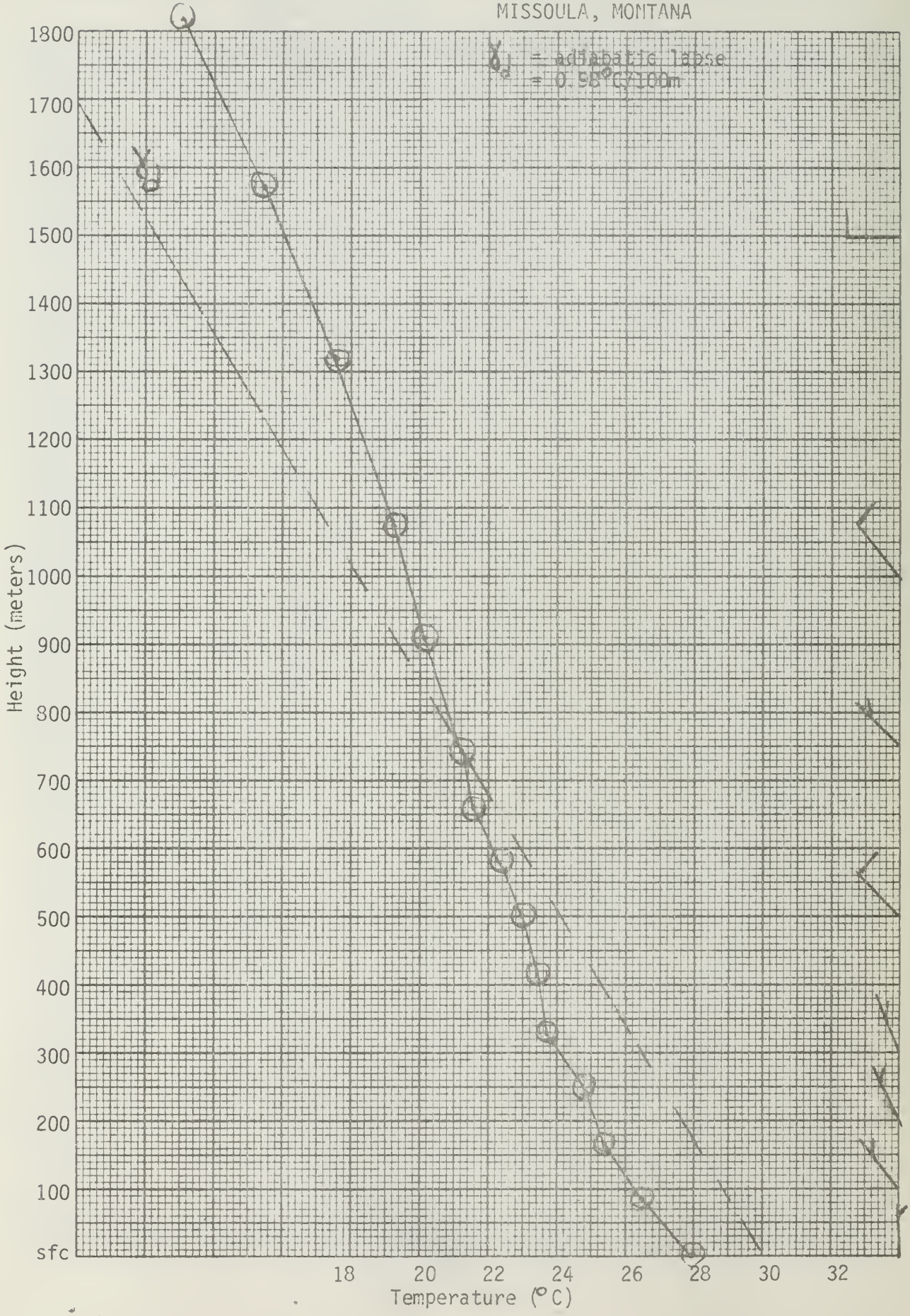
JUNE 1979
AFTERNOON
AVE. NONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA



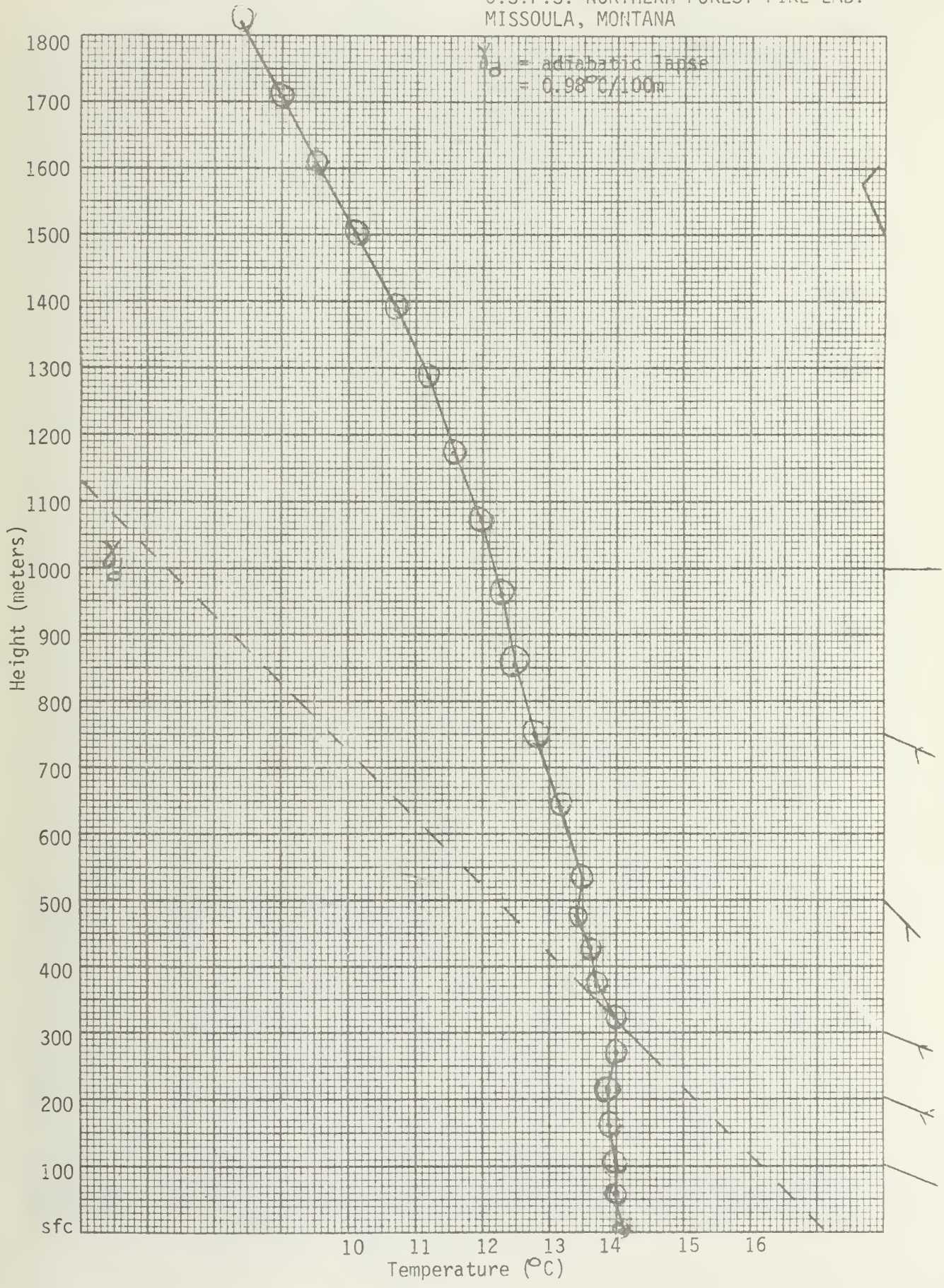
JULY 1979
MORNING
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA



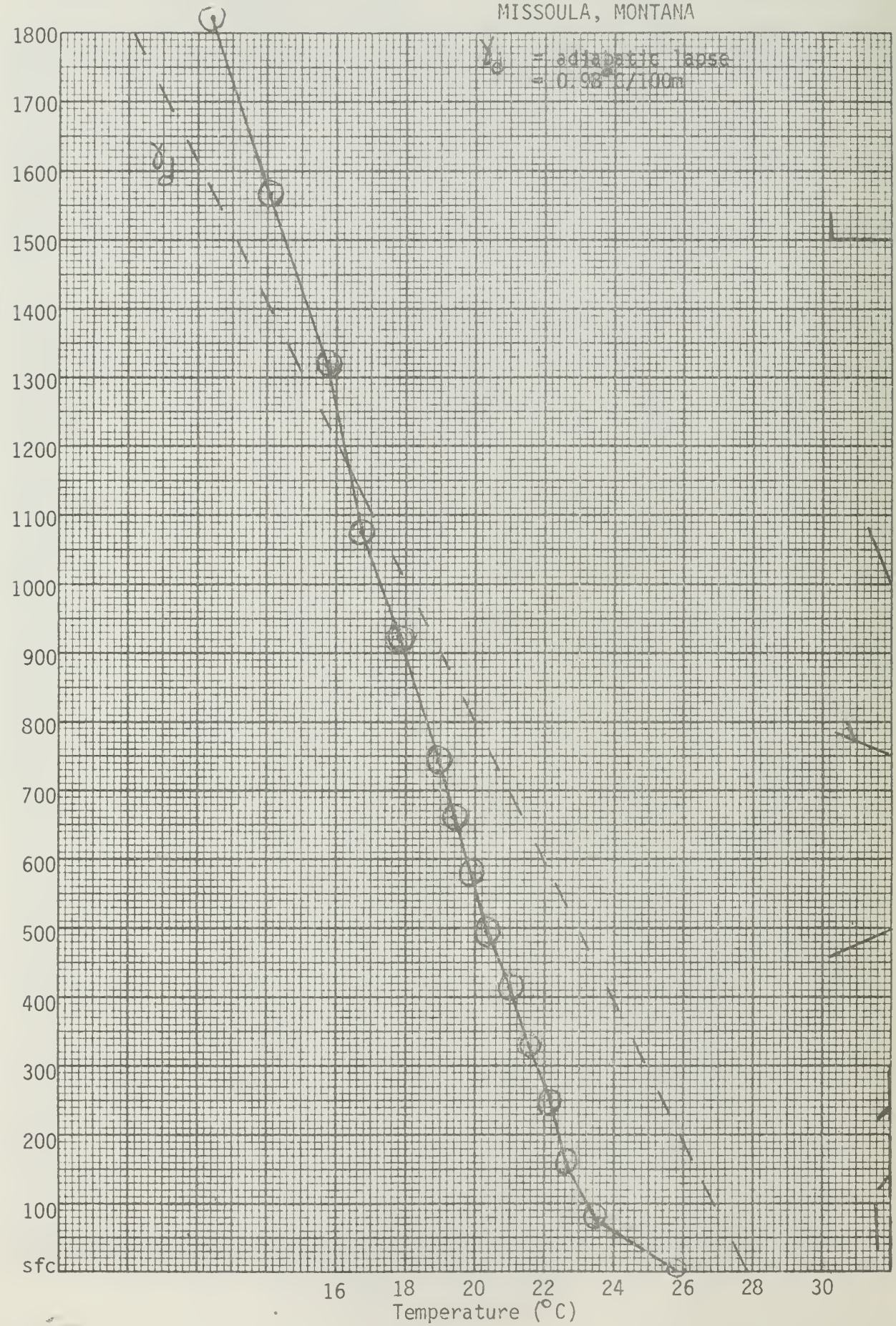
JULY 1979
AFTERNOON
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S.NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA

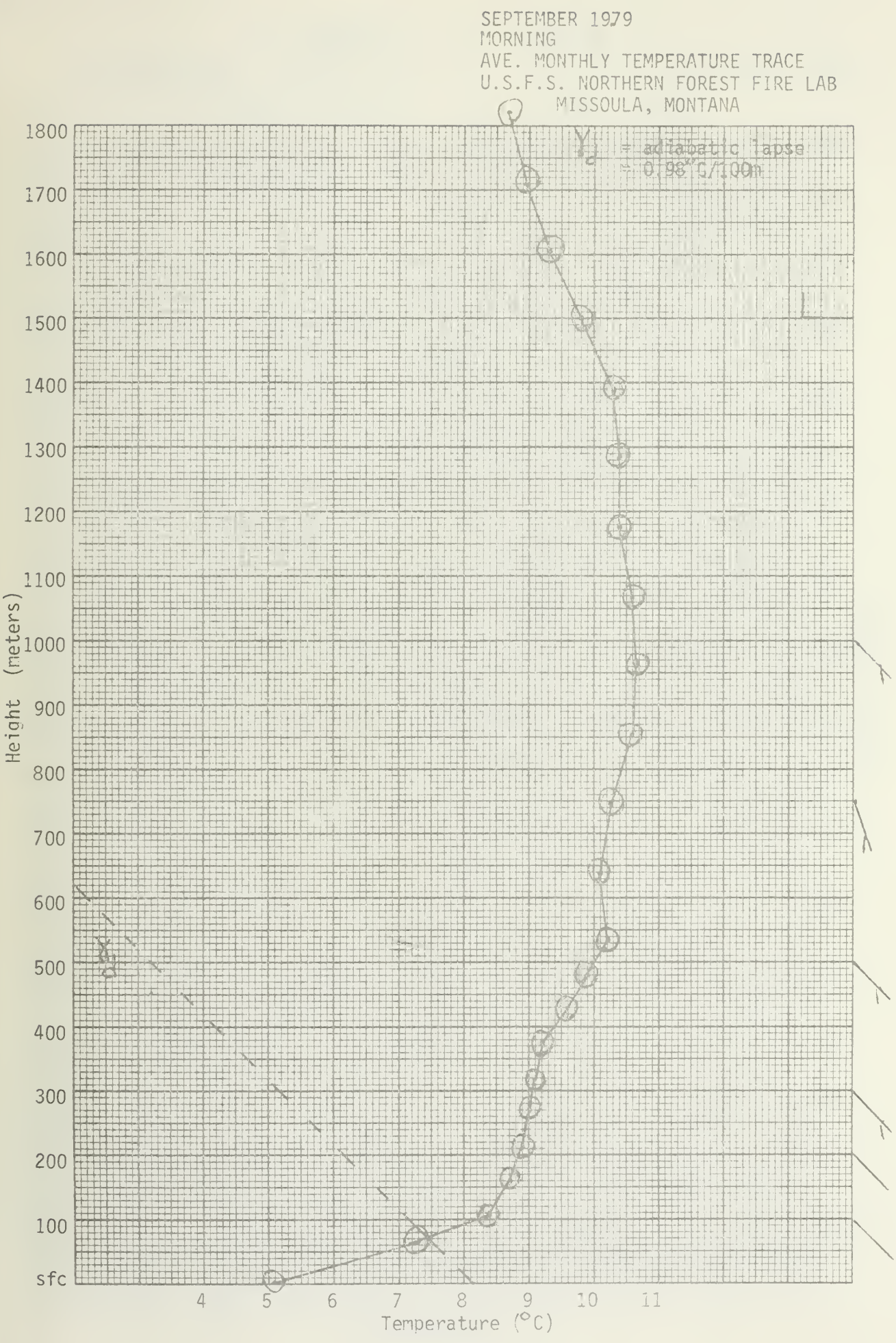


CLEARPRINT PAPER CO. NO. C310 20 DIVISIONS PER INCH BOTH WAYS 120 BY 180 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1015

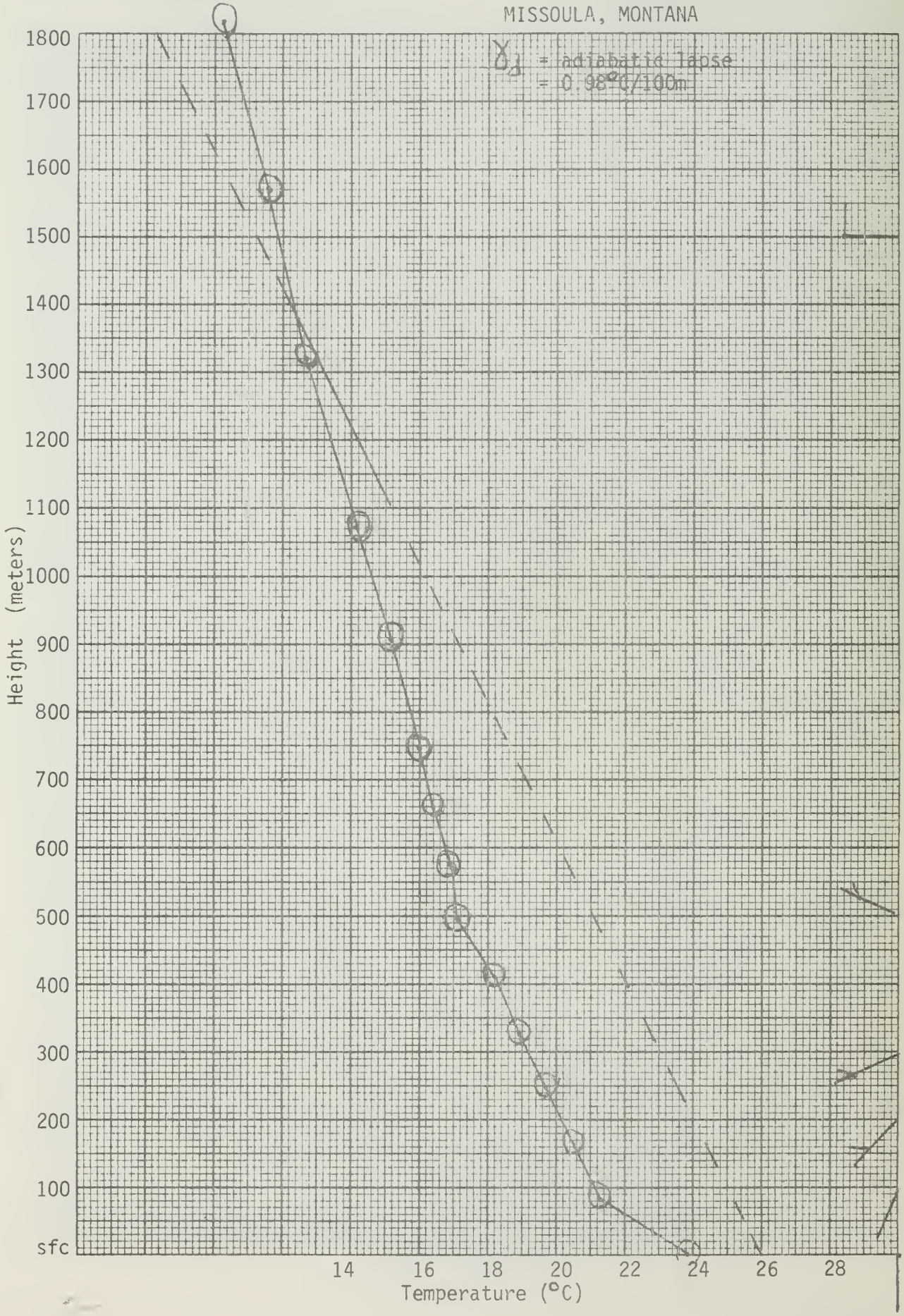

AUGUST 1979
MORNING
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA
γ_d = adiabatic lapse
= 0.98°C/100m
Height (meters)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sfc
10
11
12
13
14
15
16
Temperature (°C)

AUGUST 1979
AFTERNOON
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA

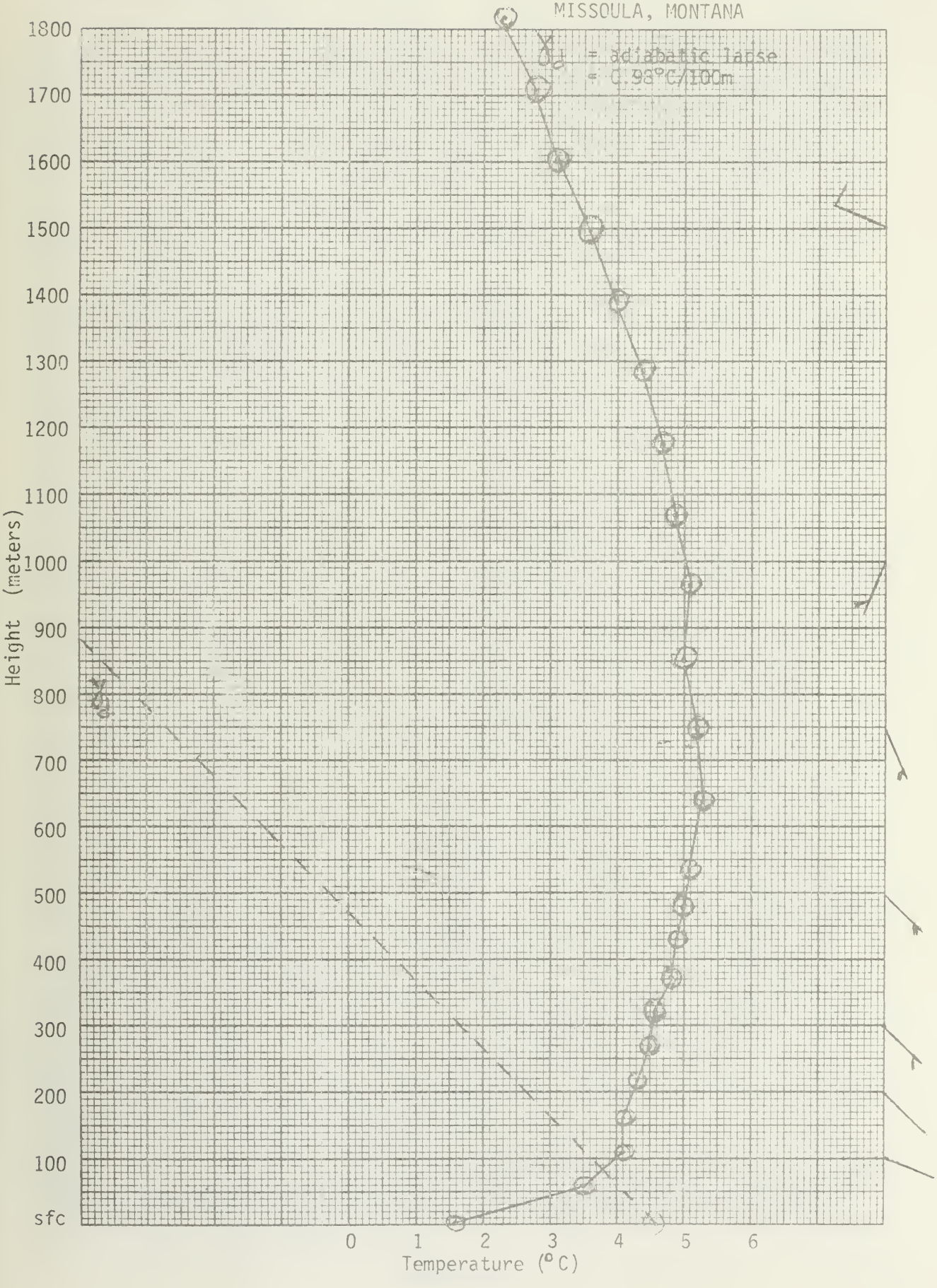



SEPTEMBER 1979
MORNING
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB
MISSOULA, MONTANA
γ_d = adiabatic lapse
≒ 0.98°C/100m
Height (meters)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sfc
4
5
6
7
8
9
10
11
Temperature (°C)

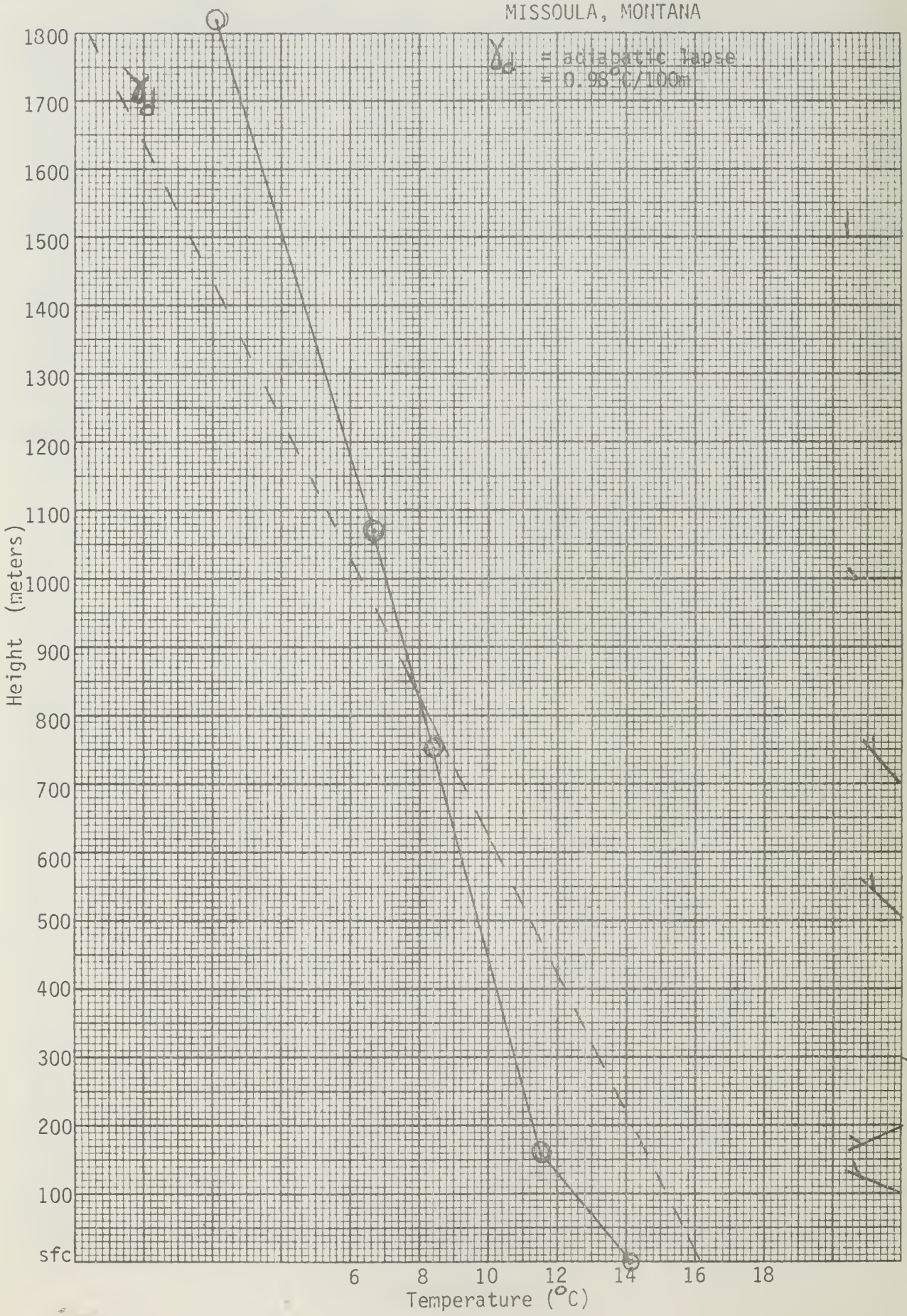
SEPTEMBER 1979
AFTERNOON
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA



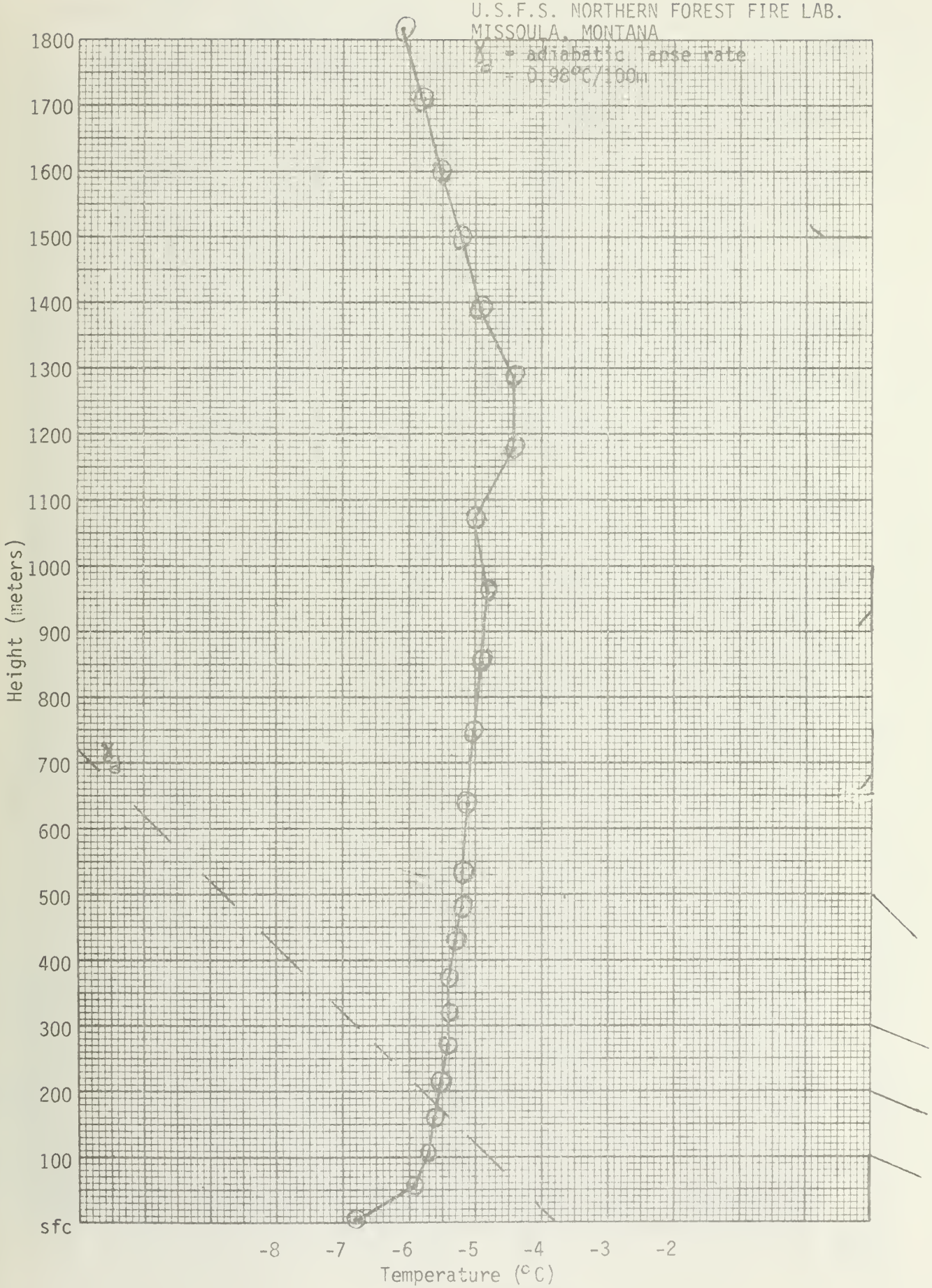
CLEARPRINT PAPER CO. NO. C310. 20 DIVISIONS PER INCH BOTH WAYS. 150 BY 198 DIVISIONS.
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1015

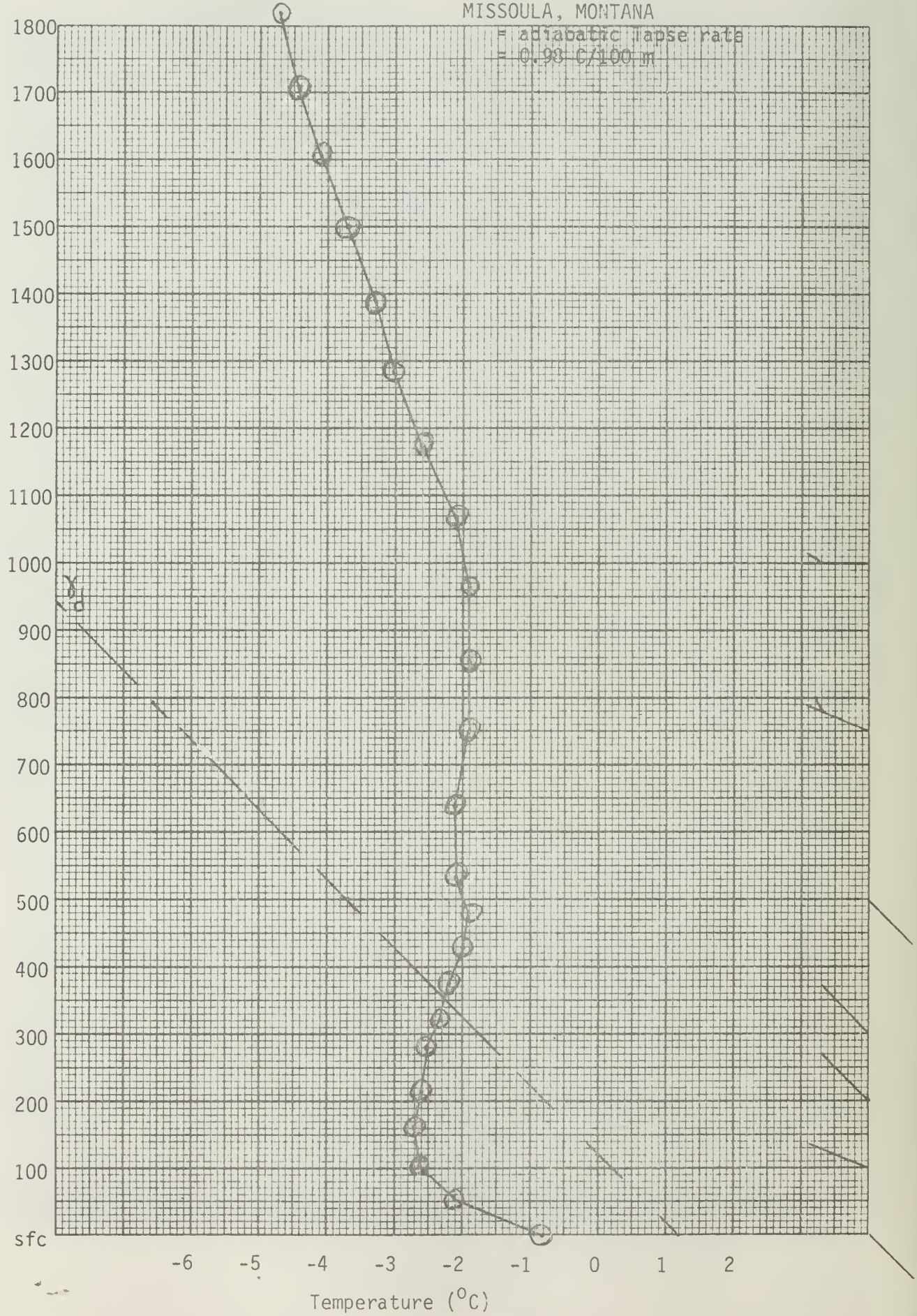

OCTOBER-1979
MORNING
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA
= adiabatic lapse
= 0.98°C/100m
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sfc
Height (meters)
0
1
2
3
4
5
6
Temperature (°C)

OCTOBER 1979
AFTERNOON
AVE. MONTHLY TEMPERATURE TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA



CLEARPRINT PAPER CO. NO. C310 20 DIVISIONS PER INCH BOTH WAYS 120 BY 180 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1015


NOVEMBER 1979
MORNING
AVE. MONTHLY TEMP, TRACE
U.S.F.S. NORTHERN FOREST FIRE LAB.
MISSOULA, MONTANA
γ_d = adiabatic lapse rate
= 0.98°C/100m
Height (meters)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
sfc
-8
-7
-6
-5
-4
-3
-2
Temperature (°C)



CLEARPRINT PAPER CO NO. C310 20 DIVISIONS PER INCH BOTH WAYS 120 BY 180 DIVISIONS
PRINTED IN U.S.A. ON CLEARPRINT TECHNICAL PAPER NO. 1015

TIME - MORNING
YEAR - 1978
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

MIXING HEIGHTS - NUMBER OF OCCURRENCES

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
0-100							3	2	1	7	6	1			5	14	
101-250							5	5	2	6	2	2			10	10	
251-500							0	3	3	0	6	5			3	9	
501-750							1	0	3	0	0	0			1	3	
751-1000							0	1	1	0	0	0			1	1	
1001-1500							0	0	0	0	1	0			0	1	
>1500							0	0	0	1	0	0			0	1	
Total							9	11	10	14	15	8			20	39	

*two months only

MIXING HEIGHTS - PERCENT OCCURRENCE

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
0-100							33.3	18.2	10.0	50.0	40.0	12.5			25.0	35.9	
101-250							55.6	45.4	20.0	42.8	13.3	25.0			50.0	25.6	
251-500							0.0	27.2	30.0	0.0	40.0	62.5			15.0	23.1	
501-750							11.1	0.0	30.0	0.0	0.0	0.0			5.0	7.7	
751-1000							0.0	9.1	10.0	0.0	0.0	0.0			5.0	2.6	
1001-1500							0.0	0.0	0.0	0.0	6.7	0.0			0.0	2.6	
>1500							0.0	0.0	0.0	7.1	0.0	0.0			0.0	2.6	

AVERAGE WIND SPEED THROUGH MIXED LAYER (m/sec)

							2.0	2.2	3.9	1.8	2.0	3.1			2.1	2.4	

TIME - AFTERNOON
YEAR - 1978
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY

MIXING HEIGHTS - NUMBER OF OCCURRENCES

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
0-100							0	0	0	0	0	0			0	0	
101-250							0	1	0	0	3	3			1	3	
251-500							1	3	2	2	5	2			4	9	
501-750							2	1	3	3	1	0			3	7	
751-1000							0	1	0	1	2	1			1	3	
1001-1500							0	0	1	2	0	0			0	3	
>1500							2	3	4	4	0	0			5	8	
Total							5	9	10	12	11	6			14	33	

*-two months only

MIXING HEIGHTS - PERCENT OCCURRENCE

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
0-100							0.0	0.0	0.0	0.0	0.0	0.0			0.0	0.0	
101-250							0.0	11.1	0.0	0.0	27.3	50.0			7.1	9.1	
251-500							20.0	33.3	20.0	16.7	45.4	33.3			28.6	27.3	
501-750							40.0	11.1	30.0	25.0	9.1	0.0			21.4	21.2	
751-1000							0.0	11.1	0.0	8.3	18.2	16.7			7.1	9.1	
1001-1500							0.0	0.0	10.0	16.7	0.0	0.0			0.0	9.1	
>1500							40.0	33.3	40.0	33.3	0.0	0.0			35.7	24.2	

AVERAGE WIND SPEED THROUGH MIXED LAYER (m/sec)

							4.6	3.7	6.6	3.7	1.9	3.1			4.2	4.1	

YEAR - 1979
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

MIXING HEIGHTS - NUMBER OF OCCURRENCES

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
0-100	2	0	5	2	4	5	4	0	13	9	6		3	11	9	28	
101-250	2	3	2	2	4	2	6	3	2	5	4		7	8	11	11	
251-500	6	3	2	3	4	1	0	2	1	3	5		14	9	3	9	
501-750	0	2	1	2	0	1	0	1	0	1	3		2	3	2	4	
751-1000	0	0	0	0	1	1	0	1	0	0	1		0	1	2	1	
1001-1500	0	1	0	0	0	1	0	0	0	0	0		1	0	1	0	
>1500	0	0	0	0	0	0	0	1	0	0	0		0	0	1	0	
Total	10	9	10	9	13	11	10	8	16	18	19		27	32	29	53	

MIXING HEIGHTS - PERCENT OCCURRENCE

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
0-100	20.0	0.0	50.0	22.2	30.8	45.4	40.0	0.0	81.2	50.0	31.6		11.1	34.4	31.0	52.8	
101-250	20.0	33.3	20.0	22.2	30.8	18.2	60.0	37.5	12.5	27.8	21.0		25.9	25.0	37.9	20.8	
251-500	60.0	33.3	20.0	33.3	30.8	9.1	0.0	25.0	6.2	16.7	26.3		51.8	28.1	10.3	17.0	
501-750	0.0	22.2	10.0	22.2	0.0	9.1	0.0	12.5	0.0	5.6	15.8		7.4	9.4	6.9	7.5	
751-1000	0.0	0.0	0.0	0.0	7.8	9.1	0.0	12.5	0.0	0.0	5.3		0.0	3.1	6.9	1.9	
1001-1500	0.0	11.1	0.0	0.0	0.0	9.1	0.0	0.0	0.0	0.0	0.0		3.7	0.0	3.4	0.0	
>1500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	0.0		0.0	0.0	3.4	0.0	

AVERAGE WIND SPEED THROUGH MIXED LAYER (m/sec)

	1.7	4.4	2.6	3.0	1.8	3.5	1.6	3.1	1.4	1.5	2.1		3.1	2.5	2.7	1.7	

TIME - AFTERNOON
YEAR - 1979
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY

MIXING HEIGHTS - NUMBER OF OCCURRENCES

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
0-100	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	
101-250	2	3	1	0	0	0	0	0	0	1	3		8	1	0	4	
251-500	4	4	3	0	0	0	0	1	0	0	7		10	3	1	7	
501-750	0	1	3	0	1	1	0	0	0	2	1		1	4	1	3	
751-1000	0	1	0	2	2	0	2	2	1	3	0		2	4	4	4	
1001-1500	0	0	0	0	1	2	0	4	5	3	0		0	1	6	8	
>1500	0	0	3	4	4	5	2	3	3	2	1		0	11	10	6	
Total	6	9	10	6	8	8	4	10	9	11	12		21	24	22	32	

MIXING HEIGHTS - PERCENT OCCURRENCE

HEIGHT(m)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
0-100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0	0.0	
101-250	33.3	33.3	10.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	25.0		38.1	4.2	0.0	12.5	
251-500	66.7	44.4	30.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	58.3		47.6	12.5	4.5	21.9	
501-750	0.0	11.1	30.0	0.0	12.5	12.5	0.0	0.0	0.0	18.2	8.3		4.8	16.7	4.5	9.4	
751-1000	0.0	11.1	0.0	33.3	25.0	0.0	50.0	20.0	11.1	27.3	0.0		9.5	16.7	18.2	12.5	
1001-1500	0.0	0.0	0.0	0.0	12.5	25.0	0.0	40.0	55.6	27.3	0.0		0.0	4.2	27.3	25.0	
>1500	0.0	0.0	30.0	66.6	50.0	62.5	50.0	30.0	33.3	18.2	8.3		0.0	45.8	45.4	18.8	

AVERAGE WIND SPEED THROUGH MIXED LAYER (m/sec)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
1.3	2.8	3.6	8.5	4.4	6.1	7.5	4.1	4.3	4.9	1.6		2.4	5.5	5.9	3.6	

INVERSION STUDY - FREQUENCY OF OCCURRENCE
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

MORNING
DATE/TIME - SPRING 1979

INVERSION BASE HEIGHT (m)

THICKNESS (m)	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1-100	9.2	2.3	9.2	11.5	3.4	5.7	3.4	3.4		48.1
101-250	16.1	2.3	4.6	6.9	9.2	1.1	5.7	0.0		45.9
251-500	1.1	0.0	1.1	1.1	1.1	0.0	1.1	0.0		5.5
501-750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	26.4	4.6	14.9	19.5	13.7	6.8	10.2	3.4		99.5
NO INVERSIONS										1

AFTERNOON
DATE/TIME - SPRING 1979

1-100	0.0	0.0	3.8	7.7	7.7	0.0	11.5	26.9	0.0	57.6
101-250	3.8	3.8	3.8	7.7	3.8	3.8	3.8	3.8	3.8	38.1
251-500	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0	3.8
501-750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	3.8	3.8	7.6	19.2	11.5	3.8	15.3	30.7	3.8	99.5
NO INVERSIONS										10

INVERSION STUDY - FREQUENCY OF OCCURRENCE HOLZWORTH CLASSIFICATION
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING SPRING 1979

INVERSION BASE HEIGHT (m)

HOLZ. INV. TYPE	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1	3.4	3.4	6.9	10.3	3.4	5.7	6.9	1.1		41.1
2	4.6	1.1	8.0	8.0	9.2	1.1	1.1	2.3		35.4
3	16.1	0.0	0.0	1.1	1.1	0.0	2.3	0.0		20.6
4	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		2.3
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	26.4	4.5	14.9	19.4	13.7	6.8	10.3	3.4		99.4

DATE/TIME - AFTERNOON SPRING 1979

1	0.0	0.0	7.7	3.8	11.5	0.0	15.4	26.9	0.0	65.3
2	0.0	3.8	0.0	7.7	0.0	3.8	0.0	3.8	3.8	22.9
3	3.8	0.0	0.0	7.7	0.0	0.0	0.0	0.0	0.0	11.5
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	3.8	3.8	7.7	19.2	11.5	3.8	15.4	30.7	3.8	99.7

INVERSION STUDY - FREQUENCY OF OCCURRENCE
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING SUMMER 1979

INVERSION BASE HEIGHT (m)

THICKNESS (m)	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1-100	4.8	2.8	3.8	5.7	8.6	9.5	3.8	5.7		44.7
101-250	8.6	0.9	3.8	10.5	6.7	3.8	5.7	2.8		42.8
251-500	4.8	0.9	0.9	2.8	1.9	0.0	0.0	0.9		12.2
501-750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	18.2	4.6	8.5	19.0	17.2	13.3	9.5	9.4		99.7
NO INVERSIONS										0

DATE/TIME - AFTERNOON SUMMER 1979

1-100	0.0	0.0	0.0	0.0	9.1	0.0	27.3	9.1	36.4	81.9
101-250	0.0	0.0	0.0	9.1	9.1	0.0	0.0	0.0	0.0	18.2
251-500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
501-750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	9.1	18.2	0.0	27.3	9.1	36.4	100.1
NO INVERSIONS										15

INVERSION STUDY - FREQUENCY OF OCCURRENCE HOLZWORTH CLASSIFICATION

SITE - U.S.F.S. FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING
SUMMER 1979

INVERSION BASE HEIGHT (m)

HOLZ. INV. TYPE	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1	0.0	0.0	0.0	8.6	8.6	8.6	6.7	6.7		39.2
2	6.7	2.8	6.7	9.5	6.7	4.8	2.8	2.8		42.8
3	9.5	1.9	1.9	1.0	1.0	0.0	0.0	0.0		15.3
4	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.9
5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0		1.0
TOTAL	18.1	4.7	8.6	19.1	17.3	13.4	9.5	9.5		100.2

DATE/TIME - AFTERNOON
SUMMER 1979

1	0.0	0.0	0.0	9.1	18.2	0.0	9.1	9.1	18.2	63.7
2	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	9.1	18.2
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	9.1
4	0.0	0.0	0.0	0.0	0.0	0.0	9.1	0.0	0.0	9.1
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	9.1	18.2	0.0	27.3	9.1	36.4	100.1

INVERSION STUDY - PERCENT FREQUENCY OF OCCURRENCE

SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

MORNING
DATE/TIME - AUTUMN 1979

INVERSION BASE HEIGHT (m)

THICKNESS (m)	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1-100	1.3	0.9	2.6	5.2	7.8	3.5	7.8	7.0	0.9	37.0
101-250	11.3	0.4	3.5	7.8	7.0	4.3	6.1	6.5	0 0	46.9
251-500	3.9	0.0	1.7	2.6	2.6	1.3	1.3	0.0	0.0	13.4
501-750	1.3	0 0	0.0	0.4	0.9	0.0	0.0	0.0	0.0	2.6
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0.0
TOTAL	17.8	1.3	7.8	16.0	18.3	9.1	15.2	13.5	0.9	99.9
NO INVERSIONS										0

AFTERNOON
DATE/TIME - AUTUMN 1979

1-100	0.0	0.0	2.6	7.8	9.1	2.6	6.5	7.8	10.4	46.8
101-250	0.0	0.0	6.5	3.9	5.2	2.6	6.5	2.6	6.5	33.8
251-500	0.0	1.3	2.6	5.2	3.9	2.6	0.0	1.3	0.0	16.9
501-750	0.0	0.0	0.0	0.0	0 0	0.0	1.3	0.0	0.0	1.3
>750	0 0	0.0	1.3	0 0	0.0	0 0	0 0	0.0	0.0	1.3
TOTAL	0.0	1.3	13.0	16.9	18.2	7.8	14.3	11.7	16.9	100.1
NO INVERSIONS										5

PERCENT

INVERSION STUDY - FREQUENCY OF OCCURRENCE HOLZWORTH CLASSIFICATION

SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

MORNING
DATE/TIME - AUTUMN 1979

INVERSION BASE HEIGHT (m)

HOLZ. INV. TYPE	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1	0.0	0.4	2.6	3.5	7.4	2.6	6.1	7.4	0.9	30.9
2	3.0	0.4	4.8	10.4	8.9	4.3	7.4	4.8	0.0	44.0
3	10.4	0.4	0.4	2.2	2.2	2.2	0.9	0.9	0.0	19.6
4	4.3	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0	5.2
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4
TOTAL	17.7	1.2	7.8	16.1	18.5	9.1	15.3	13.5	0.9	100.1

AFTERNOON
DATE/TIME - AUTUMN 1979

1	0.0	0.0	6.5	3.9	9.1	2.6	7.8	7.8	14.3	52.0
2	0.0	0.0	3.9	7.8	3.9	2.6	5.2	2.6	2.6	28.6
3	0.0	1.3	1.3	5.2	5.2	2.6	0.0	1.3	0.0	16.9
4	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	1.3
5	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3
TOTAL	0.0	1.3	13.0	16.9	18.2	7.8	14.3	11.7	16.9	100.1

INVERSION STUDY - FREQUENCY OF OCCURRENCE

SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING
SUMMER 1978
(Two months only)

INVERSION BASE HEIGHT (m)

THICKNESS (m)	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1-100	3.8	2.5	8.9	10.1	1.3	8.9	7.6	5.1		48.2
101-250	10.1	1.3	3.8	8.9	7.6	5.1	3.8	1.3		41.9
251-500	2.5	0.0	0.0	2.5	2.5	0.0	0.0	1.3		8.8
501-750	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.3
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	17.7	3.8	12.7	21.5	11.4	14.0	11.4	7.7		100.2
NO INVERSIONS										1

DATE/TIME - AFTERNOON
SUMMER 1978
(Two months only)

1-100	9.5	0.0	9.5	4.8	4.8	4.8	14.3	28.6	9.5	85.8
101-250	0.0	0.0	0.0	0.0	0.0	4.8	0.0	4.8	0.0	9.6
251-500	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.0	4.8
501-750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	9.5	0.0	9.5	4.8	4.8	9.6	14.3	38.2	9.5	100.2
NO INVERSIONS										3

INVERSION STUDY - FREQUENCY OF OCCURRENCE HOLZWORTH CLASSIFICATION

SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING
SUMMER 1978
(Two months only)

INVERSION BASE HEIGHT (m)

HOLZ. INV. TYPE	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1	0.0	2.5	2.5	7.6	2.5	3.8	5.1	2.5		26.5
2	3.8	0.0	2.5	5.1	5.1	5.1	3.8	1.3		26.7
3	10.1	0.0	6.3	7.6	3.8	3.8	2.5	3.8		37.9
4	2.5	1.3	1.3	1.3	0.0	1.3	0.0	0.0		7.7
5	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1.3
TOTAL	17.7	3.8	12.6	21.6	11.4	14.0	11.4	7.6		100.1

DATE/TIME - AFTERNOON
SUMMER 1978
(Two months only)

1	0.0	0.0	4.8	0.0	4.8	0.0	4.8	28.6	4.8	47.8
2	4.8	0.0	4.8	0.0	0.0	9.5	9.5	9.5	0.0	38.1
3	4.8	0.0	0.0	4.8	0.0	0.0	0.0	0.0	4.8	14.4
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	9.6	0.0	9.6	4.8	4.8	9.5	14.3	38.1	9.6	100.3

INVERSION STUDY - FREQUENCY OF OCCURRENCE

SITE - U.S.F.S. NORTHERN FOREST FIRE
MISSOULA, MONTANA

DATE/TIME - MORNING
AUTUMN 1978

INVERSION BASE HEIGHT (m)

THICKNESS (m)	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1-100	1.5	0.0	2.3	6.9	7.7	3.1	4.6	7.7		33.8
101-250	9.2	1.5	4.6	5.4	6.9	7.7	4.6	5.4		45.3
251-500	6.2	0.0	3.1	3.8	1.5	0.8	1.5	0.8		17.7
501-750	1.5	0.0	0.0	0.8	0.8	0.0	0.0	0.0		3.1
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	18.4	1.5	10.0	16.9	16.9	11.6	10.7	13.9		99.9
NO INVERSIONS										4

DATE/TIME - AFTERNOON
AUTUMN 1978

1-100	0.0	1.7	0.0	12.1	12.1	6.9	5.2	12.1		50.1
101-250	0.0	0.0	3.4	6.9	6.9	1.7	3.4	13.8		36.1
251-500	0.0	0.0	6.9	1.7	1.7	1.7	1.7	0.0		13.7
501-750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0 0
TOTAL	0.0	1.7	10.3	20.7	20.7	10.3	10.3	25.9		99.9
NO INVERSIONS										7

INVERSION STUDY - FREQUENCY OF OCCURRENCE HOLZWORTH CLASSIFICATION

SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING
AUTUMN 1978

INVERSION BASE HEIGHT (m)

HOLZ. INV. TYPE	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1	0.8	0.8	2.3	6.2	6.2	4.6	6.2	7.7		34.8
2	6.2	0.8	6.2	6.9	9.2	5.4	4.6	3.8		43.1
3	7.7	0.0	1.5	3.8	1.5	0.8	0.0	2.3		17.6
4	3.8	0.0	0.0	0.0	0.0	0.8	0.0	0.0		4.6
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	18.5	1.6	10.0	16.9	16.9	11.6	10.8	13.8		100.1

DATE/TIME - AFTERNOON
AUTUMN 1978

1	0.0	1.7	6.9	5.2	8.6	6.9	5.2	15.5		50.0
2	0.0	0.0	1.7	12.1	10.3	1.7	3.4	6.9		36.1
3	0.0	0.0	1.7	1.7	1.7	0.0	0.0	3.4		8.5
4	0.0	0.0	0.0	1.7	0.0	1.7	0.0	0.0		3.4
5	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0		1.7
TOTAL	0.0	1.7	10.3	20.7	20.6	10.3	10.3	25.8		99.7

INVERSION STUDY - FREQUENCY OF OCCURRENCE

SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING
WINTER 1978-1979

INVERSION BASE HEIGHT (m)

THICKNESS (m)	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1-100	5.4	0.0	2.2	6.5	2.2	4.3	5.4	8.7		34.7
101-250	4.3	5.4	5.4	8.7	9.8	2.2	7.6	4.3		47.7
251-500	2.2	1.1	0.0	3.3	1.1	3.3	3.3	0.0		14.3
501-750	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0		3.3
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	11.9	6.5	10.9	18.5	13.1	9.8	16.3	13.0		100.0
NO INVERSIONS										1

DATE/TIME - AFTERNOON
WINTER 1978-1979

1-100	1.3	2.6	7.7	7.7	7.7	3.8	6.4	5.1	1.3	43.6
101-250	1.3	3.8	9.0	11.5	7.7	3.8	2.6	7.7	0.0	47.4
251-500	0.0	1.3	3.8	0.0	0.0	1.3	0.0	1.3	0.0	7.7
501-750	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	1.3
>750	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	2.6	7.7	20.5	20.5	15.4	8.9	9.0	14.1	1.3	100.0
NO INVERSIONS										2

INVERSION STUDY - FREQUENCY OF OCCURRENCE HOLZWORTH CLASSIFICATION

SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

DATE/TIME - MORNING
WINTER 1978-1979

INVERSION BASE HEIGHT (m)

HOLZ. INV. TYPE	SFC	1-100	101-250	251-500	501-750	751-1000	1001-1500	1501-2000	>2000	TOTAL
1	1.1	1.1	2.2	6.5	2.2	4.3	5.4	8.7		31.5
2	4.3	3.3	6.5	2.2	6.5	1.1	6.5	1.1		31.5
3	3.3	2.2	2.2	8.7	4.3	3.3	4.3	2.2		30.5
4	3.3	0.0	0.0	1.1	0.0	1.1	0.0	1.1		6.6
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		0.0
TOTAL	12.0	6.6	10.9	18.5	13.0	9.8	16.2	13.1		100.1

DATE/TIME - AFTERNOON
WINTER 1978-1979

1	0.0	1.3	6.4	6.4	9.0	2.6	5.1	5.1	1.3	37.2
2	1.3	3.8	7.7	10.2	3.8	2.6	1.3	5.1	0.0	35.8
3	1.3	2.6	6.4	3.8	2.6	3.8	2.6	3.8	0.0	26.9
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	2.6	7.7	20.5	20.4	15.4	9.0	9.0	14.0	1.3	99.9

YEAR - 1979
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

AVERAGE LAPSE RATE IN FIRST INVERSION (C/100m) - MORNING

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
1.52	0.89	1.66	1.02	1.37	1.50	1.19	1.00	2.39	1.79	1.61		1.24	1.28	1.26	1.93	

AVERAGE LAPSE RATE BELOW FIRST INVERSION (C) - MORNING

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
-1.29	-1.15	-0.96	-0.51	-0.56	-0.41	0.00	-0.72	-0.18	-0.76	-0.71		-1.09	-0.68	-0.38	-0.55	

PERCENT FREQUENCY OF SURFACE BASED FIRST INVERSIONS - MORNING

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
20.0	44.4	90.0	45.4	69.2	75.0	80.0	25.0	93.8	68.4	57.9		40.7	69.7	63.3	72.2	

AVERAGE LAPSE RATE IN FIRST INVERSION (C/100m) - AFTERNOON

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
0.65	1.22	0.78	0.43	0.74	0.36	0.24	0.52	0.32	0.55	1.62		0.98	0.64	0.34	0.83	

AVERAGE LAPSE RATE BELOW FIRST INVERSION (C) - AFTERNOON

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
-1.05	-1.66	-0.87	-0.92	-0.90	-0.58	-1.39	-0.83	-0.84	-1.04	-1.44		-1.25	-0.90	-0.93	-1.11	

PERCENT FREQUENCY OF SURFACED BASED FIRST INVERSIONS - AFTERNOON

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM	AUT	ANNUAL
0.0	10.0	9.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		8.0	3.8	0.0	0.0	

YEAR - 1978
SITE - U.S.F.S. NORTHERN FOREST FIRE LABORATORY
MISSOULA, MONTANA

AVERAGE LAPSE RATE IN FIRST INVERSION (C/100m) - MORNING

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
						2.54	1.38	0.70	1.61	1.68	1.23			1.87	1.45	

AVERAGE LAPSE RATE BELOW FIRST INVERSION (C) - MORNING

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
						-0.00	-0.69	-0.56	0.00	-0.80	-0.84			-0.34	-0.45	

PERCENT FREQUENCY OF SURFACE BASED FIRST INVERSIONS - MORNING

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
						77.8	63.6	20.0	100.0	53.3	62.5			70.0	57.8	

*two months only

AVERAGE LAPSE RATE IN FIRST INVERSION (C/100m) - AFTERNOON

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
						0.70	0.48	0.63	0.85	0.73	1.02			0.55	0.74	

AVERAGE LAPSE RATE BELOW FIRST INVERSION (C) - AFTERNOON

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
						-1.06	-1.26	-0.96	-1.07	-0.81	-1.05			-1.16	-0.98	

PERCENT FREQUENCY OF SURFACED BASED FIRST INVERSIONS - AFTERNOON

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WTR	SPR	SUM*	AUT	ANNUAL
						16.7	10.0	0.0	0.0	0.0	11.1			12.5	0.0	

APPENDIX B

GLOSSARY OF METEOROLOGICAL TERMS

The following terms were taken from the Glossary of Terms Frequently Used in Air Pollution, published by the American Meteorological Society.

AIR POLLUTION - The general term alluding to the undesirable addition to the atmosphere of substances (gases and liquids and solid particles) either that are foreign to the "natural" atmosphere or in quantities exceeding their natural concentrations.

AIR QUALITY - The composition of air with respect to quantities of pollutants therein; used most frequently in connection with "standards" of maximum acceptable pollutant concentrations.

ANEMOMETER - The general name for instruments designed to measure the speed (or force) of the wind.

ATMOSPHERIC PRESSURE - (Also called barometric pressure) The pressure exerted by the atmosphere as a consequence of gravitational attraction exerted upon the "column" of air lying directly above the point in question. As with any gas, the pressure exerted by the atmosphere is ultimately explainable in terms of bombardment by gas molecules; it is independent of the orientation of the surface on which it acts.

Atmospheric pressure is one of the basic meteorological elements. It is measured by many varieties of barometer, and is expressed in several units systems. The most common unit used is the millibar (1 millibar equals 1000 dynes per cm^2). Unique to the science of meteorology is the use of inches (or millimeters) of mercury; that is, the height of a column of mercury that exactly balances the weight of the column of atmosphere whose base coincides with that of the mercury column. Also employed are units of weight per area and units of force per area. A standard atmosphere has been defined in terms of equivalence to each of the above unit systems, and it is used as a unit itself.

CIRCULATION PATTERN - The general geometric configuration of atmospheric circulation at a given time and region.

COTTON-REGION SHELTER - A medium-sized instrument shelter used extensively at second-order stations, climatological substations, etc. It is a white louvered box with a flat double roof and is mounted four feet above the ground on a four-legged stand.

CLEAN AIR - A political term alluding to the chemical and optical condition of the atmosphere back in the good old days.

DEW POINT - (Or dew point temperature) The temperature to which a given parcel of air must be cooled at constant pressure and constant water-vapor content in order for saturation to occur.

FREE LIFT - The actual lifting force of an inflated balloon, usually expressed in grams. The free lift plus the weight of the balloon and attached equipment is the total lift.

INSTRUMENT SHELTER - (Or thermometer shelter; also called thermoscreen, thermometer screen) A box-like structure designed to protect certain meteorological instruments from exposure to direct sunshine, precipitation, and condensation, while at the same time providing adequate ventilation. Instrument shelters are painted white, have louvred sides, usually a double roof, and are mounted on a stand several feet above the ground with the door side facing poleward.

Instrument shelters are meant to house thermometric instruments, such as psychrometers, maximum and minimum thermometers, hygrothermographs, etc.

INVERSION - In meteorology, a departure from the usual decrease or increase with altitude of the atmospheric propery; also, the layer through which this departure occurs (the "inversion layer") or the lowest altitude at which the departure is found (the 'base of the inversion"). This term almost always means a temperature inversion.

INVERSION LAYER - A layer in the atmosphere through which the temperature remains constant or increases with altitude.

LAPSE RATE - The decrease of an atmospheric variable with height, the variable being temperature, unless otherwise specified.

MIXING HEIGHT - (Or mixing depth) The thickness of the atmospheric layer, measured from the surface upward, through which pollutants are presumed to mix by virtue of convection caused by daytime heating at the surface. The designation of mixing height implies the existence of an inversion, in which case the mixing height is also the height of the inversion base.

PILOT BALLOON - A small balloon whose ascent is followed by a theodolite in order to obtain data for the computation of the speed and direction of winds in the upper air.

PILOT-BALLOON OBSERVATION - (Commonly contracted pibal) A method of winds-aloft observation; that is, the determination of wind speeds and directions in atmosphere above a station. This is done by reading the elevation and azimuth angles of a theodolite while visually tracking a pilot balloon.

The ascension rate of the balloon is approximately determined by careful inflation to a given total lift. After release from the ground, periodic readings (usually at one-minute intervals) of elevation and azimuth angles of the balloon are recorded. These data are transferred to a winds-aloft plotting board, and the wind speed and direction at selected levels are calculated by trigonometric methods.

PREVAILING WIND DIRECTION - (Or prevailing wind) The wind direction most frequently observed during a given period. The periods most frequently used are the observational day, month, season and year.

SOLAR RADIATION - The total electromagnetic radiation emitted by the sun.

STABLE - Pertaining to the atmosphere or an atmospheric layer in the condition of static stability, that is, an atmosphere whose temperature lapse rate and moisture distribution is such as to suppress vertical exchange of air.

STAGNATION - With respect to air pollution, the persistence of a given volume of stable air over a region, permitting an abnormal buildup of pollutants from sources within the region.

STATIC STABILITY - (Also called hydrostatic stability, vertical stability, convective or convectional stability) The state of the atmosphere when it is stable relative to vertical displacements. Such an atmosphere tends to remain stratified, in that any air that is displaced vertically is subjected to a buoyant force that tends to restore it to its original level.

Static stability is determined primarily by the temperature lapse rate; an inversion layer is an extreme example of a statically stable layer.

SURFACE INVERSION - (Or ground inversion) A temperature inversion based at the earth's surface; that is, an increase of temprature with height beginning at the ground level.

This condition is due primarily to greater radiative loss of heat at and near the surface than at levels above. Thus, surface inversions are common over land prior to sunrise and in winter over high-latitude continental interiors.

TEMPERATURE INVERSION - A layer in which temperature increases with altitude. The principal characteristic of an inversion layer is its marked static stability, so that very little turbulent exchange can occur within it. Strong wind shears often occur across inversion layers, and abrupt changes in concentrations of atmospheric particulates and atmospheric water vapor may be encountered on ascending through the inversion.

When, in meteorological literature and discussion an "inversion" is mentioned, a temperature inversion is usually meant.

THEODOLITE - An optical instrument which consists of a sighting telescope mounted so that it is free to rotate around horizontal and vertical axes, and graduated scales so that the angles of rotation may be measured. The telescope is usually fitted with a right-angle prism so that the observer continues to look horizontally into the eyepiece, whatever the variation of the elevation angle. In meteorology, the theodolite is used principally to observe the motion of a pilot balloon.

TOTAL LIFT - The upward force produced by the gas in a balloon. It is equal to the sum of the free lift, the weight of the balloon, and the weight of auxiliary equipment carried by the balloon.

VISIBILITY - 1. In United States weather observing practice, the greatest distance in a given direction at which it is just possible to see and identify with the unaided eye (a) in the daytime, a prominent dark object against the sky at the horizon, and (b) at night, a known, preferably unfocused, moderately intense light source. After visibilities have been determined around the entire horizon circle, they are resolved into a single value of prevailing visibility for reporting purposes.

VISUAL RANGE - (Or daytime visual range) The distance, under daylight conditions, at which the apparent contrast between a specified type of target and its background becomes just equal to the threshold contrast of an observer; to be distinguished from the night visual range. The visual range is a function of the atmospheric extinction coefficient, the albedo and visual angle of the target, and the observer's threshold contrast at the moment of observation. Only in the so-called meteorological range does one have a visibility figure dependent only upon the extinction coefficient.

WIND - Air in motion relative to the surface of the earth. Since vertical components of atmospheric motion are relatively small, especially near the surface of the earth, meteorologists use the term to denote almost exclusively the horizontal component. Vertical winds are always identified as such.

WIND ROSE - Any one of a class of diagrams designed to show the distribution of wind direction experienced at a given location over a considerable period; it thus shows the prevailing wind direction. The most common form consists of a circle from which eight or sixteen lines emanate, one for each compass point. The length of each line is proportional to the frequency of wind from that direction; and the frequency of calm conditions is entered in the center. Many variations exist. Some indicate the range of wind speeds from each direction; some relate wind directions with other weather occurrences.

WIND VANE - An instrument used to indicate wind direction.

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